June/July, 1980
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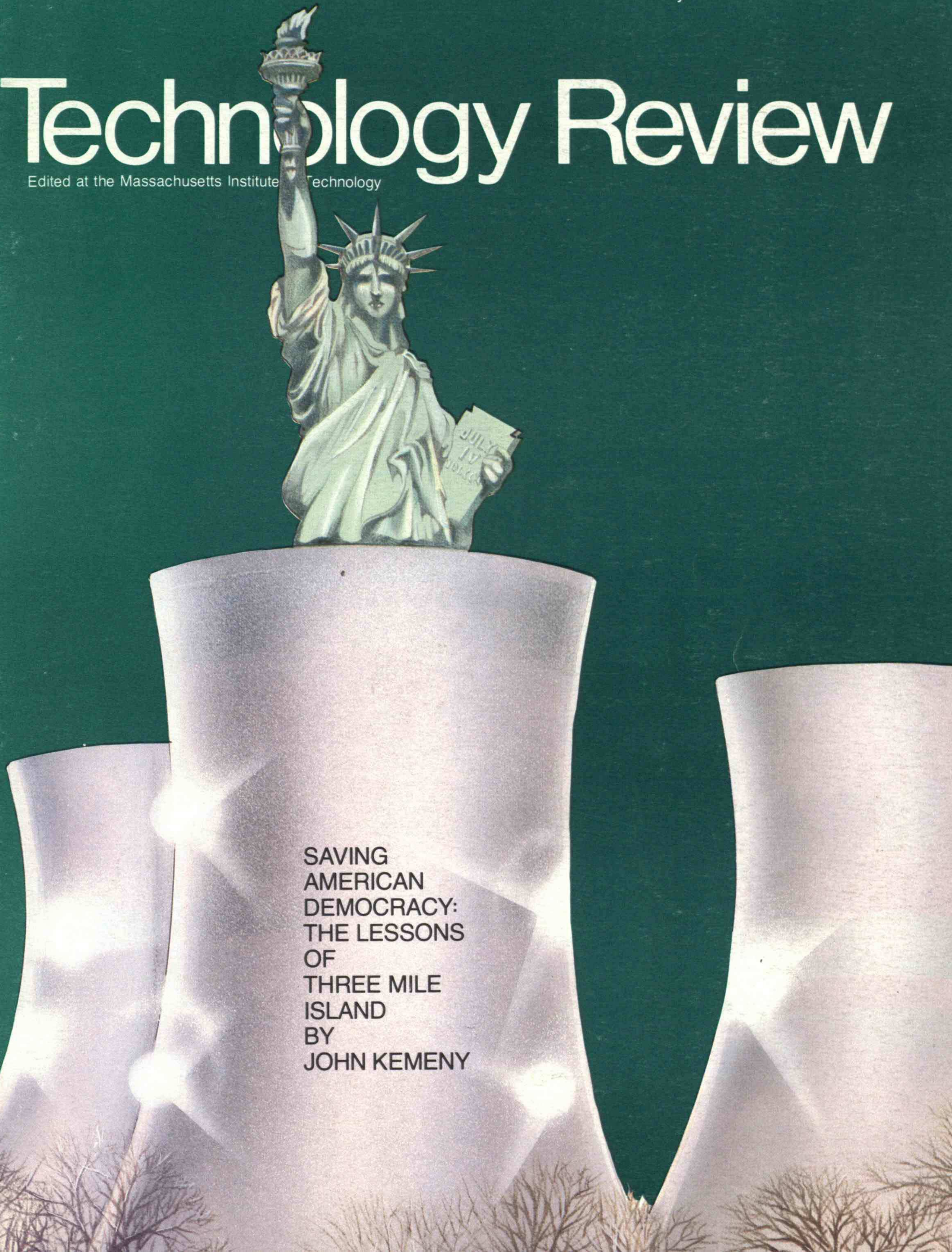
Is Nuclear Regulated or Chained?
What Good Is Expert Advice?
The Universality of Language
D.O.E. Money for Inventors

Technology Review

Edited at the Massachusetts Institute of Technology



SAVING AMERICAN DEMOCRACY: THE LESSONS OF THREE MILE ISLAND BY JOHN KEMENY

WHAT DO YOU THINK IT IS?

Need some help?

Then consider the following:

The car you're looking at has a CIS fuel-injected engine that can take you from 0 to 50 in 8.5 seconds.

And power-assisted disc drum brakes that can take you from 50 to 0 in less than three.

It has 4-wheel independent suspension to keep you from going like this on bad roads.

And front-wheel drive to give you responsive handling even in bad weather.

In back, there's a trunk so large it can hold six suitcases.

All standing up.

And inside, there's room enough for a family of four.

Got it yet?

Well, maybe it would help to know that for all its impressive performance on the road, this car still turns in a pretty spectacular performance at the gas pump.

It gets an EPA estimated $\boxed{25}$ mpg, 40 mpg estimated highway. (Use "estimated mpg" for comparisons. Your mileage may vary with weather, speed and trip length. Actual highway mileage will probably be less.)

You <u>still</u> don't know?

Then we should probably mention one last thing.

This car doesn't look like what it is, and most people have a hard time guessing.

So why don't we just tell you.

We call it the Jetta.

Of course, Autoweek had a different name for it.

They called it, "another winner from Volkswagen."

THINK AGAIN.

Edited at the Massachusetts Institute of Technology
Volume 83, Number 7
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Technology Review

Saving American Democracy: The Lessons of Three Mile Island
Page 64

Cover illustration by Roger Leyonmark
Cover design by Jacqueline Casey

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First Line

The Lady on the Cover

Jacqueline S. Casey's favorite lady is Frederic Auguste Bartholdi's "Liberty" — incidental information made pertinent by the cover design for this issue.

Since 1955, when she came to M.I.T. as a graphic designer, Ms. Casey has made her way into the first rank of designers. Her designs — especially her posters — have been in countless exhibitions and publications of outstanding U.S. graphics; they are in the permanent collections of the Museum of Modern Art (New York) and the Library of Congress. Ms. Casey is a member of the Board of Directors of the American Institute of Graphic Arts and the review panel of the Visual Communication Section of the National Endowment for the Arts. She has helped jury a number of national exhibitions and has lectured at Yale, Carnegie-Mellon, Simmons, and the Massachusetts College of Art (her *alma mater*).

The *Review* is honored that she accepted our assignment for the cover of this issue, which turns out to be Ms. Casey's first magazine cover; and she and the *Review* are both honored, in turn, by the illustrator Roger Leyonmark's rendition of her concept. —*J.M.*

And the Lady on Page 28

A special word is also appropriate about the illustration on page 28 and its creator, Gini Holmes.

The illustration is an example of a new genre — copy art — created by a new kind of designer: an electrographic artist.

For as long as we know, artists have been quick to turn to new technologies as sources of new images. It was true of stone lithography, originally invented to reproduce sheet music easily and quickly; and of the laser, originally conceived as a scientific tool.

Copy art results from artists' use of office copying machines as new creative instruments. They are tools of great variety; almost every one of the many different designs of machines makes images idiosyncratic to that particular machine. Hence the artistic variety and skill embraced in copy art.

Ms. Holmes' copy art was included in one of the first exhibitions of work in this new medium (Amsterdam, October 1979). She is now a graduate student pursuing work as an electrographic artist in the Visible Language Workshop at M.I.T. —*J.M.*

Letters

Cockroaches to the Moon!

William Sauber (*"Evolutionary Imperative," December/January, p. 4*) attributes people's ascension from the cave to the moon as an "evolutionary imperative of nature" — a prime example of John Ruskin's "pathetic fallacy," ascribing will and normative power to a goddess called "nature." Why just people? Why not cockroachs, whose age is an order of magnitude greater? (Of course, they may walk on the moon some day, too — if we carelessly take them there.)
Arthur J. Morgan
New York, N.Y.

Tax Breaks for Information Processors?

Paul Strassmann (*"The Office of the Future," December/January, pp. 54-65*) points out that a large proportion of employees now deal solely with information, and that information processing is done to a large extent with computers. The development of minicomputers is now making it possible for many information processors to work at home, transmitting the results of their labors to a central office by telephone data-link. If the practice spreads, we will see a decrease in commuting by white-collar workers — and perhaps a corresponding decrease in gasoline consumption. Promoting the practice — perhaps through a tax break for employers who supply their information processors with home computers — could be a significant energy-conservation strategy.
Thomas A. Easton
Unity, Maine

No Nukes!

I'm sorry to see that more and more writers — of graffiti and otherwise — (*see "The Writing on the Wall," December/ January, p. 85*) are being taken in by what appears to be a deliberate semantic trick — using the term "nukes" indiscriminately for nuclear power plants and nuclear bombs. One might as well call conventional power plants "big fires" or stress that a car we dislike is "explosion-powered." Since the deaths at Hiroshima, rather than the absence of deaths at Ten Mile Island, give emotional impact to the word "nukes," it is clear why this linkage is encouraged by those who are out to generate a fear of nuclear power by fair means or foul.
E. Scott Pattison
Dunedin, Fla.

Bicycles to Like and Not to Like

The article by David Gordon Wilson (*"Getting in Gear: Human-Powered Transportation, October, 1979 pp. 42-54*) was remarkable in its omission of the cam bicycle, invented by Lawrence Brown (M.I.T.'55). Brown's invention is nothing short of a major step forward in this area: in all tests, Brown's cam drive gave a 10-to-20-per-cent lesser heart rate, oxygen consumption, and pulse for the same power output on a wide range of subjects with a broad range of fitness levels. It broke all U.S. records it went after, and is being seriously considered for use by the U.S. Olympic team in 1980.
T. Ross
Honolulu, Hawaii

Professor Wilson responds:

If the cam-drive bicycle transmission does all that Mr. Ross claims for it, I must agree that it will be a substantial benefit. For years researchers in human-power production have tested various foot motions involving different harmonics in the relative motion with the chainwheel and such variations as oval chainwheels, linear drives, swinging levers, and so forth; and no one has up to now been able to prove a consistent superiority over the plain circular crank and chainwheel. A cam-drive transmission adds the friction and mass of a rather large cam and a one-way clutch ("freewheel") running backwards part-time, which would appear on the surface to be drawbacks. However, the results cited by Mr. Ross suggest that Mr. Brown's development gives a greatly improved impedance match between leg muscles and bicycle. As it has other advantages over present chain transmissions (continuous change in gear ratio, a wider range of ratio, and a decreased susceptibility to road grit and other hazards), the cam should make a substantial impact in the future. One always assumes that any device or procedure that enables athletes to achieve higher outputs will also allow ordinary mortals to produce much lower outputs with more comfort and less fatigue. There is an interesting research program to test this hypothesis.

In the 1930s I rode throughout several square miles of eastern Queens (New York City) on my bicycle; it enabled me to go places I couldn't otherwise have reached without bothering my parents; it was fun; and it was part of my youth. Recently I received a bike as a present, and riding it as a middle-aged adult was quite a different experience. I like the light weight, the ten speeds, and the narrow, high-pressure tires that make pedaling so much easier. But I do not like the handlebars that make me look at the roadway instead of where I'm going and give me a pain in the neck, the hand-operated brakes (what became of my old coaster brake?) that I must *learn* to use, the tiny seat (it is only perhaps ten uncomfortable square inches in area and becomes really painful after a half-hour), and the lack of markings on the controls.
Albert Sanders
Woodside, N.Y.

Professor Wilson responds:

Mr. Sanders has found that the "racing" style of bicycle is not for everyone. He could, with some difficulty and expense, replace his hard, narrow saddle with a more comfortable type. And improved and easier-to-use brakes and gears have been developed; indeed, one can, or could, buy three-speed hub gears incorporating coaster ("back-pedaling") brakes. Although these usually work well in wet weather, in contrast to most rim brakes, they also can be extremely dangerous. When the chain becomes worn, it frequently comes off the sprockets, and then one has no brake whatsoever. Mr. Sanders is almost writing a specification for a semi-recumbent bicycle like my own. But he would find the lightweight "roadster" or "sports" bicycle, with a sprung saddle, upturned handlebars, and three- or five-speed hub gears, a good compromise.

The Longevity of Magnetic Bearings

I take exception to the statement *(see "Flywheels for Energy Storage" by Alan R. Millner, November 1979, pp. 32-40)* that the lifetime of magnetic systems is not limited by loading. The dynamic equilibrium position (or levitation gap) in a magnetic bearing decreases with age because gravity acts against such a vertical system at a near-constant rate. Although the rotor remains "weightless," the magnetic pressure dissipates at a rate proportional to the amount of net loading. I

have found such a dissipation rate to be 0.75 percent per year for minimal loading of a floating rotor and 2.8 percent per year for maximum loading with a vertical system using ceramic ferrite clusters with linear bearings. Rare-earth cobalt magnets are tremendously efficient when used in suspension devices, but they, too, must follow a similar path of power dissipation when positioned to cancel the force of gravity at a constant rate with respect to time and extent of net loading. The life of such a vertical system can be extended with small reductions in the mass of the rotor to keep the dynamic equilibrium position nearly constant.

Mr. Millner's estimated bus-bar cost with the solar link ($1,720 per kilowatt) is realistic, and his projection of life-cycle energy cost ($0.067 per kilowatt hour in residential use) will most certainly be competitive with local utility rates in the mid-1980s.
Tom Day
Fulton, Mo.

Mr. Day is director of the Missouri Energy League. Dr. Millner comments:
Minor changes in magnet strength will certainly occur over the projected 20-year life span of these flywheel devices, and the important parameter is the magnitude of those changes. The rare-earth cobalt magnets used in our magnetic bearings are far more resistant to demagnetization than ferrites, and at projected operating temperatures the expected demagnetization over the life of the system totals only a few percent. This is most easily adjusted by changing the magnetic air gap in the bearings electronically.

Aflatoxin and Carcinogens

In his review (*February, pp. 16, 18*) of Dr. Samuel Epstein's *The Politics of Cancer,* Leonard Reiffel shows the same disregard and misapplication of fact as are evident in the book he reviews, thus presenting a picture that is completely different from the facts as I know them:

□ A 1966 World Health Organization recommendation for a maximum tolerated level of aflatoxin in peanut meal, to be used as a protein supplement in countries such as India under the conditions prevailing in 1966, is interpreted by Dr. Reiffel as a proposal for all foods for all time. Also, the units of micrograms per kilogram (ug/kg) of peanut meal are incorrectly presented as ug/kg body weight; the lowest level of aflatoxin tested in the rat was 1 ug/kg of diet, not 0.5 ug/kg.

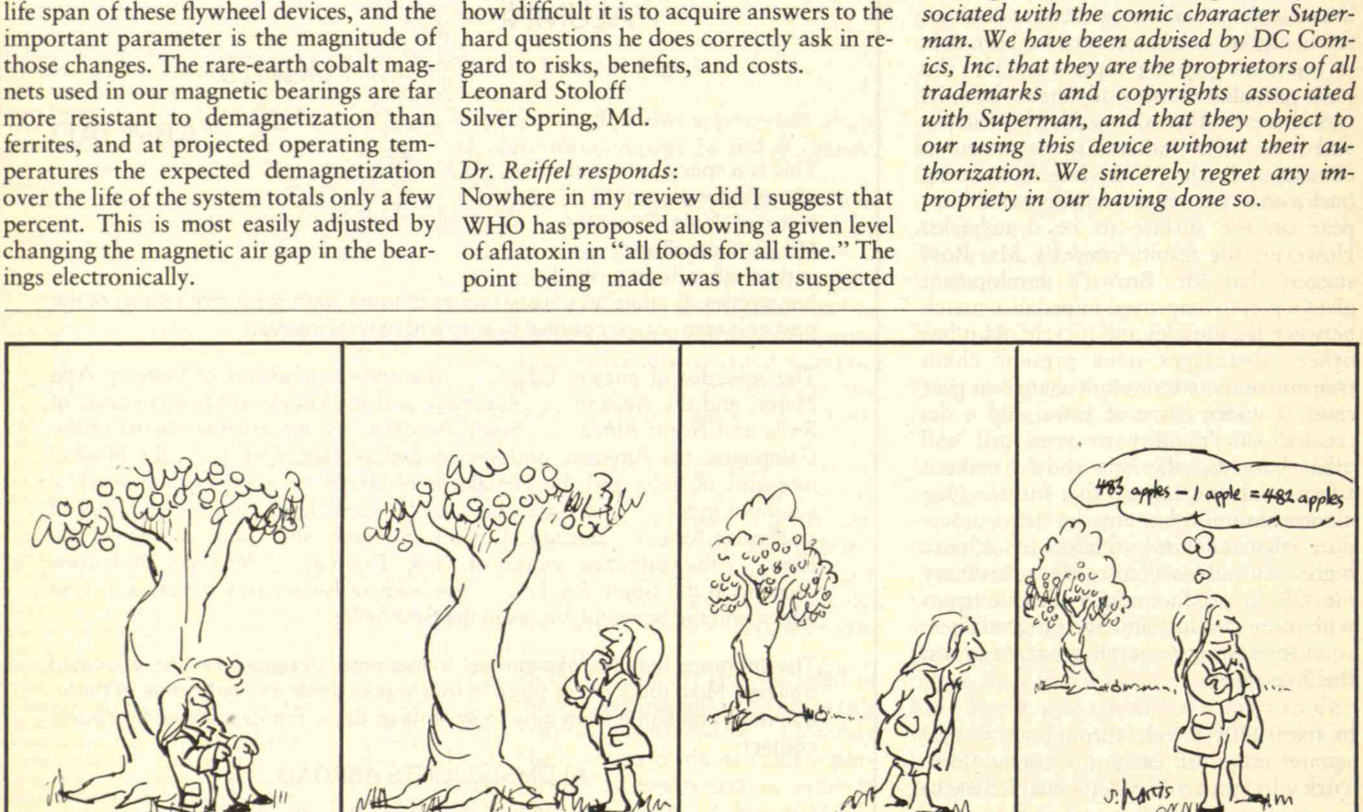
□ Sterigmatocystin is not "considered a universal contaminant of wheat and flour" by any responsible investigator, nor has sterigmatocystin been reported as a natural contaminant in any acceptable food or feed.

Had Dr. Reiffel been more knowledgeable in regard to aflatoxins he might have been able to use them as an example of how difficult it is to acquire answers to the hard questions he does correctly ask in regard to risks, benefits, and costs.
Leonard Stoloff
Silver Spring, Md.

Dr. Reiffel responds:
Nowhere in my review did I suggest that WHO has proposed allowing a given level of aflatoxin in "all foods for all time." The point being made was that suspected natural carcinogens have been consciously permitted in human food, and I was contrasting this unarguable fact with the handling of man-made carcinogens as discussed in the Epstein book. Stoloff is correct in his comment concerning the units used in the WHO recommendation. This mis-statement resulted from an error during editing of the final manuscript; correcting the units has no effect whatever on my argument.

P. Grasso and C. O'Hare of the British Industrial Biological Research Association, who are the authors of the chapter "Carcinogens in Food" in the American Chemical Society's major and recent monograph on *Chemical Carcinogens*, state (*p. 720*), "Clearly sterigmatocystin may be as important a carcinogen in terms of its actual hazard to man as the more carcinogenic aflatoxin." Sterigmatocystin is specifically listed as a "universal" contaminant of wheat and flour.

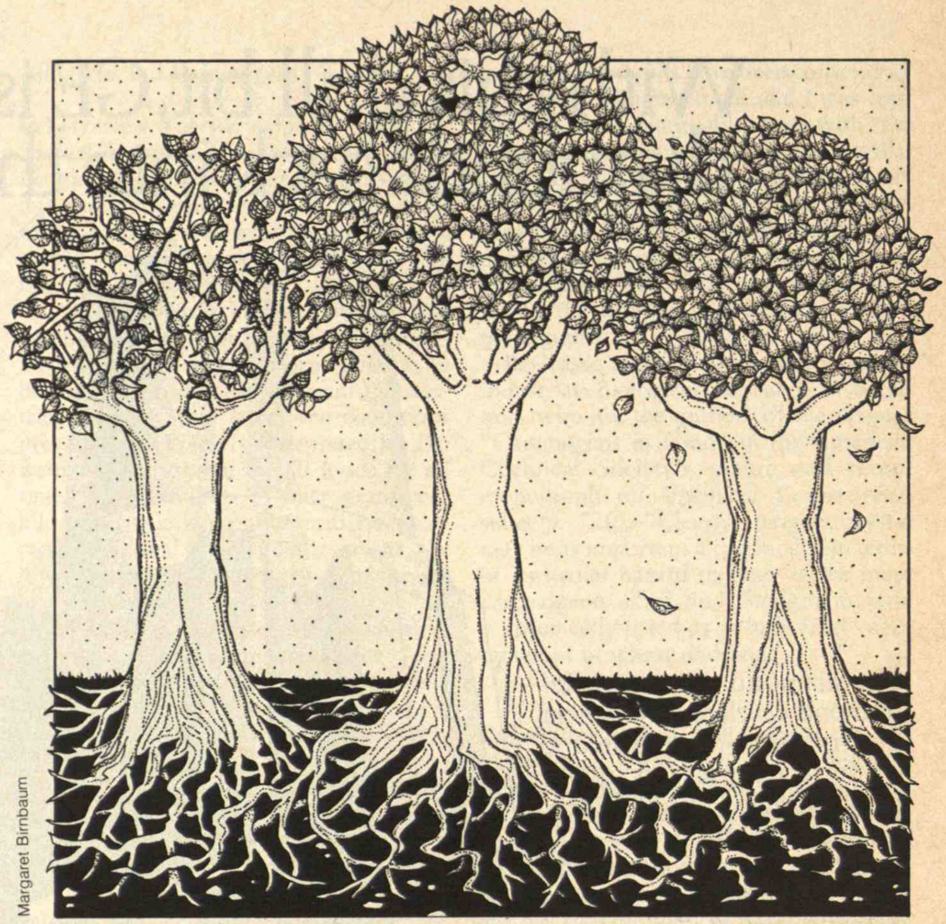
Correction notice: The cover of the March/April, 1980 issue of Technology Review *included an illustration of a man with his shirt opened and wearing a t-shirt bearing the "S" device generally associated with the comic character Superman. We have been advised by DC Comics, Inc. that they are the proprietors of all trademarks and copyrights associated with Superman, and that they object to our using this device without their authorization. We sincerely regret any impropriety in our having done so.*



Sidney Harris

The Ripening Society

Kenneth E. Boulding is director of the Institute of Behavioral Science and professor of economics at the University of Colorado at Boulder. He is a regular contributor to Technology Review.



Margaret Birnbaum

Maturation is perhaps the most universal and pervasive of all natural processes. Stars, mountain ranges, lakes, corporations, nations, empires, and all living creatures are born, mature, and die. Maturation is the realization and eventual exhaustion of potential. Thus, the true believers in thermodynamics, surely the gloomiest of all the sciences, think that however the universe began, it is bound to end in a thin, uniform, cosmic soup in which nothing more can happen.

If we are honest, we have to admit that we do not know very much about the universe. So there is a possibility that even thermodynamic potential could be recreated. If it was created in the "big bang," why not again? However, we can leave that question to the philosophers, for the earth's thermodynamic potential is continually recreated by the sun's energy.

In biological organisms, to date at least, it appears impossible to recreate the potential of the original fertilized egg or divided cell. Living organisms proceed inexorably from conception to birth, childhood, maturity, and death. All the potential may not be realized, of course — environmental changes can lead to a greater or lesser degree of realization. Premature death and other forms of unrealized potential are extremely common — in fact, universal. Our original gene structure decays with age and is never renewed, as far as we know. If there are such renewals, they are very rare. In a population, however, biological potential is continually recreated as DNA replicates itself and eggs are fertilized.

Regeneration of Social Organizations

In social organizations and total societies, it is difficult to separate the genetic structure from the environmental realization of genetic potential. The situation is confused by the fact that the genetic potential of organizations, unlike biological organisms, can be renewed. This is possible because an organization or a society consists essentially of role structures united by channels of communication, and the occupants of these role structures change as the persons who occupy them retire, die, or are replaced. The genetic structures of society also consist of records of the past — documents, bibles, constitutions, even buildings and monuments — and these may be constantly reinterpreted and their significance renewed as new generations make them their own. In society, therefore, maturity may be prolonged almost indefinitely.

The United States is a beautiful example of these principles. It began as a geographic expansion, mainly of middle- and lower-class English people, into the relatively empty niche of the Atlantic seaboard of North America. The colonists carried with them the English language, customs, religions, political culture, ideas, and — perhaps most important — books (the King James Bible, Shakespeare, English law, the Magna Charta) and an oral tradition. This "cultural baggage" also contained unrealized potential, or social genetic structure.

In the early decades, the culture of the colonies did not differ much from that of England. Different environments, however, encourage different evolutionary potentials. By the middle of the eighteenth century we have a distinctively American culture, still very similar to the English culture but increasingly differentiated. This differentiation culminates in the American Revolution and the establishment of the United States and its Constitution in 1789. Here we have a fertilized social egg with a favorable environment for development, and the history of the last 200 years can certainly be written in terms of the realization of that potential. It was and is a vigorous and progressive culture, highly open to technological change and new ideas. It had a whole continent for expansion, the original inhabitants of which did not have a culture capable of occupying so large a niche. It is not surprising, therefore, that we have experienced an extraordinary, indeed unprecedented, expansion — of population, territory, knowledge, and production.

Science and science-based technology have dominated these 200 years. This oc-

curred in the temperate zones — first in Western Europe, very soon afterward in North America, quite early in Japan, and later in Eastern Europe. This led to an explosive growth of the human population, first around both temperate zones and then in the tropics. Lands relatively empty to a science-based culture were soon filled with migrants. Everywhere a huge array of new technologies, forms of energy, and human artifacts — coal, steam engines, oil and gas, electricity, aluminum, plastics, automobiles, airplanes, skyscrapers, all that we think of as the modern world — exploded into a temporarily unresistant world ecosystem.

Hardly anywhere was this explosion more striking than in North America, especially from about 1880 to 1930. This was the period of adolescent growth. The period after 1930 corresponds to young adulthood, when growth shifts away from the physical into the intellectual domain. When I came to the United States in 1932, I saw a New York not essentially different from now. I saw the Empire State Building, the Chrysler Building, Wall Street, streets full of automobiles, telephones, an airport, movies and radios — quite recognizably the modern world. If my grandfather had sailed into New York 50 years before, he would have seen a city not terribly different from that of 1783. Curiously enough, one could say the same thing about my native city of Liverpool, about San Francisco, even about Tokyo, all of which came into the modern world between 1884 and 1932.

Is the World at Its Peak?

The very critical question for the future is whether the United States and indeed all the modern world now face maturity. And, if so, how do we do it? Societies and social organizations are not biological organisms, but there are some similarities. In society, potential can be renewed, though it may not be; and the question of how to renew it is important. Furthermore, the modern world involves the exhaustion of certain nonrenewable potentials such as fossil fuels. And if new potentials are not discovered, exhaustion may lead to maturity and to death and collapse. When oil, gas, coal, and cheap materials are gone, the twenty-second or twenty-third century might look much more like the tenth than the twentieth. There is at least some possibility that the doomsayers of Rome are right.

Throughout the history of the earth — and even the universe — two dynamic processes have been in evidence, with sometimes one and sometimes the other prevailing. One is the principle of exhaustion, which might be called the "entropy law," the using up of potential. The other is the principle of "renewal," the constant formation of new potential. Biological potential, which cannot be recreated in a single individual, is recreated every time an egg is fertilized. The potential of a society or an organization is recreated by new visions of its past and by new, more dynamic individuals occupying old roles.

If we look at the future of our country, we ask ourselves what new potentials can be created to offset the exhaustion of the old ones. We cannot go back to 1620 or to 1783. We must accept the fact that we are an increasingly mature society. We are not going to expand much in population or in wealth. Nevertheless, even within this framework new potentials can be created. A society does not have to be bigger, richer, or more powerful to be better. And there are signs already that potential is being created for a society that is better rather than bigger and richer. ☐

Open Season on Hurricanes

Robert C. Cowen, science editor of the Christian Science Monitor, *is former president of the National Association of Science Writers and is a regular contributor to the* Review. *He holds S.B. and S.M. degrees in meteorology from M.I.T.*

Lucy Dillon

As this year's hurricane season opens in the North Atlantic, it's worth recalling last year's devastating duo, David and Frederic. The death and destruction they brought to the Caribbean and parts of the United States — and the mitigation of the carnage in the latter area — dramatized the importance of effective public response to the hurricane threat. And it isn't too early to consider the need for such public awareness this year.

The start of last year's hurricane season was marked by the appearance of tropical cyclone Ana off the west African coast on June 20. This was the first time since 1933 such a storm had arisen that early east of the Lesser Antilles. There had been only one other like it in the previous 100 years. Ana didn't develop into a threatening hurricane, but it could have. David and Frederic — which also began as small disturbances off Africa on August 22 and August 17, respectively — had become "multibillion-dollar storms" by the time they reached the Caribbean and eastern United States.

Warnings Left Blowing in the Wind

The differences between what happened in these two regions are stark and instructive. There was extensive property damage in both areas. Frederic, especially, was one of the most costly hurricanes the United States has experienced, doing more than $2-billion worth of destruction. But, while Frederic forced temporary evacuation of 200,000 to 300,000 people (mostly along the Mississippi-Alabama coast), "people damage" from both storms was minimal. There were about 16 fatalities in the U.S. and 9 in Puerto Rico from David, and about 8 from Frederic. Contrast this with over 1,000 deaths caused by David in the Caribbean, mostly in the Dominican Republic, and 60,000 left homeless on Dominica.

The key factor that made the difference was public awareness and response, says Neil Frank, director of the National Hurricane Center (NHC) at Coral Gables, Fla. He calls David, in particular, "an historic storm" for the United States because the public made such prudent use of the agency's forecasts and warnings — not overreacting, but boarding up and moving out when needed. In much of the Caribbean, and especially the Dominican Republic, although officials received the NHC warnings, communications were so poor that most of the people were uninformed. They were caught unprepared in homes and villages often built in watercourses for flash floods.

There's little point in belaboring such folly, especially remembering that millions of Americans along the Gulf and Eastern seaboards insist on living in hard-to-evacuate areas vulnerable to hurricane-driven tides. (*See "Acts of God Made Worse by People," by James Cornell, p. 14.*) Nor is there anything new in noting that public response is an important factor in mitigating hurricane catastrophe. What is new is to realize that hurricane meteorologists now consider public response the *only* factor that can improve the effectiveness of hurricane warning systems in the foreseeable future — or at least this decade.

Dr. Frank explains: "Hurricane forecasting here [at NHC] is no better today than it was ten years ago. There may even be some evidence that it has slightly deteriorated. With the advent of satellites, we have abandoned some older, expensive observing platforms — ships and some island stations. The main hurricane steering currents are in the low and middle levels of the atmosphere where satellite cloud pictures don't give good wind-flow indications. Aircraft are inadequate to take over the sampling job. So we are losing our ability to evaluate properly the mid-level circulation over the ocean.

"I'm not at all opposed to cutting back on those expensive conventional observing platforms. But the message is that in many coastal areas where we need more lead time with accurate forecasts — 24 hours instead of 12 hours — we are just not going to be able to provide it. We couldn't do it without losing credibility

through overwarning [forcing needless evacuation over an unnecessarily large warning area]. Radar doesn't help here; it only fine-tunes the tracking."

This doesn't mean that hurricane forecasters are giving up on trying to improve their warning system — they are only taking a realistic view of their situation. The warning system is a technological marvel. Satellites provide early spotting and continuous tracking of a storm's development over ocean areas that once were blind spots. Computerized forecasts of general weather patterns help provide guidance in projecting storm motion. Radar gives close-in tracking (with a range of about 150 miles).

Project Hurricane Strike

And those old "hurricane-hunter" flights have turned into a sophisticated probing that virtually puts the forecaster inside the storm itself. Modern aircraft can stay in the air for ten hours. Each is equipped to measure a wide range of data, including wind speed and direction, temperatures and dewpoint at aircraft level, and sea-level air pressure. Designed primarily for research, the aircraft are also used to keep continuous tabs on a hurricane for the last 40 hours prior to its expected landfall. This operation, called "Project Hurricane Strike," was inaugurated last year.

The aircraft's data along with its latitude and longitude and time of observation are recorded automatically minute by minute. Every half-hour the data are sent back to NHC in five-minute bursts via a relay statellite. Written comments by the crew, including descriptions of the eye and state of the sea, can be included. With this kind of detailed "real time" input, forecasters can narrow the zone covered by a hurricane warning and sharpen their forecasts of such major effects as the surge of wind-driven seawater or inland flooding. Even small improvements in such forecasts would be beneficial, for it's expensive to shut down business, board up, and evacuate. The narrower the zone, the more this cost can be cut.

Hurricane Wobblings

At the same time, Dr. Frank's associate, Joseph M. Pelissier, notes, "If we improve the forecast 10 percent, that would be a breakthrough. But we would still need the public response to improve the effectiveness of the warning substantially." He adds, "If I were asked to teach a course in calculus, it would be easy because the subject is so systematic. But if I were asked to teach a course in tropical cyclone forecasting, I wouldn't know where to begin. When it comes down to it, we do a lot of guessing. It's like the stock market." And this is the crucial fact of life when it comes to the bottom line of the hurricane warning system — namely, saving lives and limiting property damage.

Hurricane David illustrated the problem. When it reached Florida, it traveled along the coast after suddenly and unpredictably changing course from a straight run at Miami. Wandering like a wobbly top, it stayed just offshore until moving inland north of Palm Beach. In spite of continuous radar monitoring and "Strike" planes in the storm, the meteorologists couldn't anticipate which way the storm would wobble. They simply don't understand the small oscillations typical of hurricanes, yet such wobbles are important.

This illustrates why Dr. Frank emphasizes the role of a well-informed public that is ready to assume its share of responsibility for its own safety. This involves more than restricting occupation of vulnerable coastal areas and heeding official warnings, important as these are. It calls for a community and national effort to learn how best to build and also to plan emergency procedures for different local circumstances.

In this connection, Dr. Frank looks to Australia as an example. Before a "Willy Willy" leveled Darwin on December 25, 1974, the city had no hurricane-related building codes. After the disaster the inhabitants overreacted — builders put needlessly costly fortresses on houses. Then wind-tunnel experiments showed how adequate resistance could be built for only a 10-to-20-percent cost increase. This shows how thoughtful research, translated into practical housing design, can pay off, Dr. Frank says. Such research can point out practical ways to protect property without unreasonable expense. Likewise, careful community planning — along with wise zoning — can greatly increase the effectiveness of hurricane warnings in protecting lives. It would be a good investment. As Dr. Frank says, forecasting technology isn't going to do much more for us than it has already. □

A Closed Mouth Gathers No Feet

Edwin Diamond is a veteran journalist and author. His books include The Tin Kazoo: Television, Politics, and the News *(M.I.T. Press, 1975),* Good News, Bad News *(M.I.T. Press, 1978) on the 1976 presidential campaign, and* Jimmy Carter: An Interpretive Biography *(Simon and Schuster, 1980), coauthored with Bruce Mazlish. Formerly a senior editor with* Newsweek, *he is now senior editor of* Washington Journalism Review, *contributing editor of* Esquire, *and head of M.I.T.'s News Study Group. This article was prepared with the help of Dean Phillips and Erica Max.*

Jon McIntosh

The image of our abandoned helicopters and burned-out C-130 transport plane lying on the Iranian desert is seared into the American consciousness. And it symbolizes another enormously complex undertaking — the search for causes and culprits. Just how prepared are U.S. defense forces? How good is American maintenance? How, indeed, does American technology measure up? These questions came up late in the presidential primary races but are sure to be heard again during the election campaign.

There is an irony here, of course. The early primary campaigns of Carter, Reagan, Kennedy, Bush, Anderson, et al. marched along without much mention of science and technology. But events in Iran and Afghanistan forced the candidates to address "crisis issues": energy supplies, alternative sources, defense preparedness, and military spending in general. The tragic hostage-rescue mission, then, may at least have the ultimate salutary effect of directing attention once again to science and technology matters.

The News Study Group in the Department of Political Science at M.I.T. asked each candidate for his position papers on several technology-related issues: energy, defense, space exploration, health care, medicine, and research. Not surprisingly, these papers tended to be vague, as befits a modern presidential campaign. Of all the candidates, only Representative John Anderson provided a science and technology paper that made explicit reference to his support of expanded federal funding of research and development. Anderson said that research was one of his highest national priorities [*see box*].

The absence of candidates' statements on specific technological issues suggests something about campaign priorities. Still, when they do have something to say, it's often worth listening to with the third ear, so to speak. Campaign statements can't be dismissed as "just rhetoric." The candidates' carefully tuned words on such issues as oil reserves, the windfall profits tax, the MX system, and SALT tend to reflect deeper attitudes — the person behind the image. There may be some real choices in November regarding science and technology.

Here is a brief accounting of where the candidates (and, for comparison, a couple of ex-candidates) stand:

On nuclear energy: Edward Kennedy told a student audience at Grinell College last November that he favored "a two-year moratorium on the issuance of licenses for construction of nuclear plants. No new plants should be built until we can be certain they are safe." The issue then remained subdued until just 11 days before the primary in New Hampshire — a state where the Seabrook plant has created constituencies — when Kennedy emphasized that he also favored the phasing out of *existing* plants. The Kennedy position also holds that no nuclear waste policy "would be politically credible until it recognizes the right of states to reject the construction of waste facilities within their borders."

President Carter maintains, "My own position is that we ought to have conservation of energy as a first priority, but there is a legitimate place for nuclear power in our country." This is a shift from his nuclear-energy-as-a-last-resort position during the 1976 campaign, and it directly opposes Kennedy's calls for a moratorium. In February, Carter proposed a 15-year national effort to develop a safe method of permanently storing the radioactive wastes from reactors.

Reagan opposes "arbitrary" shutdowns of existing plants and stoppage of current construction. "Doing so could disrupt the lives and jobs of millions of Americans in areas such as New England that are heavily dependent upon nuclear power for their electricity. However, it is imperative that nuclear plants be operated safely, and that their wastes be disposed of safely as well." Reagan also contends that conservation is "no answer" to the nation's energy problem.

Anderson argues that "there should be a moratorium on the construction of nu-

clear power plants until the recommendations made by the commissions studying Three Mile Island are implemented." He advocates stepped-up research on nuclear fusion in "an attempt to lower costs and human/environmental risks. In closer examination of the problems of nuclear power (such as nuclear wastes), [they] must be satisfactorily resolved before we put more nuclear plants on the drawing board."

On energy shortages: Anderson has proposed a 50-cent "conservation tax" on gasoline to be coupled with payroll tax reductions and a relaxation of interest rates. He claims that "such a package would curb inflation and reduce energy consumption by as much as 1.2 million barrels per day." In addition, he supports Carter's decisions to impose a windfall profits tax and to deregulate crude oil prices. Anderson also favors a rationing plan, a $24-billion low-income energy assistance plan, and more research on solar and other alternative energy sources.

Reagan wants to eliminate price controls, allocation formulas, and other "restrictions." He opposes an oil import quota. But he makes a nod in the direction of alternative energy sources. "We should explore the many promising new energy technologies, such as synthetic fuels and solar energy," Reagan's position papers state. "However, we cannot afford to place total reliance on unproven methods." Reagan contends that controls "impede domestic production" and that the elimination of these controls "would increase domestic supplies by several hundred thousand barrels of oil per day."

Kennedy questions the Carter administration's proposed idea of gasoline "rationing" by raising prices, suggesting that a fairer system would be distribution by supply. He says that he is convinced Americans are "ready to make hard choices to secure control over their own energy future. The president and the nation should be willing to sacrifice a little gasoline rather than shed blood to protect OPEC pipelines in the Middle East."

On defense and security: The candidates are more evenly divided along party and ideological lines. The attitudes of Carter and Kennedy often concur when actions rather than projected policy statements are studied. Kennedy has a long record of taking the "moderate" position on defense issues. Under recent pressures to increase military spending, Kennedy has become somewhat less dovish. He remains opposed to full deployment of the MX, though not to its development. He deplores "gold-plated" military systems and has voted against a number of major weapons systems, including the B-1 bomber. Nonetheless, he favors Carter's proposed increases in military expenditures to improve conventional forces. He also favors SALT II (though it is presently tabled in Congress).

Carter's official administration summary (a printed document) highlights his efforts to preserve peace through a strong defense: continued development of the *Trident* submarine and missile system, adoption of the MX system, 3-percent growth in defense spending, and support of SALT II. The Carter campaign's television commercials stress more "philosophic" matters such as the need for "will and determination" on the part of the American people. Neither print nor television commercials mention Carter's more dovish, pre-Iran-crisis positions, including cancellation of the B-1 bomber, the neutron bomb, and a fifth nuclear fleet. Before Iran, Carter defended these actions on grounds of other priorities and of budgetary constraints.

The Republican views are slightly more hawkish. Reagan and Bush see Carter's decision to discontinue production of the B-1 bomber as a serious mistake, and they anticipate a period of grave danger to the U.S. in the mid-1980s, a period of supposed Soviet superiority. (If this sounds like echoes of John Kennedy's "missile gap" charges, an unsubstantiated flight of fancy that nevertheless helped defeat the

Continued on page 77

Rescuing R&D from Benign Neglect

The following is a condensed version of John Anderson's "Statement on Science and Technology."

My program calls for:

☐ *Redefining the working relationship between government and universities.* Our great research universities are saddled with federal rules, controls, regulations, and paperwork that stifle initiative. We must balance the government's need for reasonable accountability for the use of research funds with the universities' needs for independence and self-regulation.

☐ *A federal program to reequip the laboratories in our universities, our nonprofit research centers, and our government facilities.* The research and development establishment of the U.S. now functions, for the most part, with decaying and obsolete equipment. It is noteworthy that the rise in productivity in Europe and Japan closely parallels those nations' respective investments in research and development facilities.

☐ *Extension of the investment tax credit to cover research and development performed in the private sector.* (I am also examining, with great interest, proposals to extend the provisioning of the Defense Department's Independent Research and Development Program to other federal agencies that fund and support resource-intensive research and development activities.)

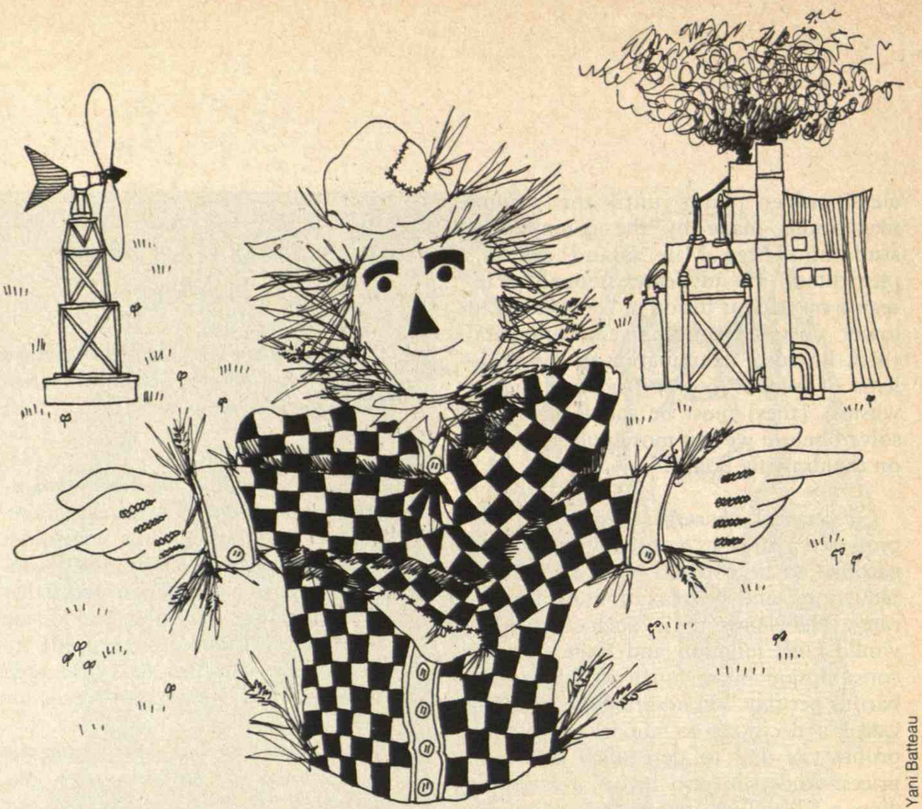
☐ *Innovative new energy policies,* emphasizing both conservation and the development of new sources of energy, which can come only from our laboratories.

☐ *A new materials policy.* The U.S. is as vulnerable to foreign interference in the flow of raw materials — such as bauxite, titanium, chromium, rubber, molybdenum, copper, and manganese — as it is vulnerable to interference with the supply of energy. No solutions are foreseeable without a stable and well-conceived long-term research program.

☐ *Insuring that the federal government carries out its responsibilities* to support R&D and creates incentives for the private sector to do so.

☐ *Providing fixed objectives for scientists and engineers on the cutting edge of technology.* They are handicapped by a regulatory environment that presents a moving target of changing goals and objectives.

Our declining R&D effort represents an extraordinarily shortsighted policy for a nation that prides itself on clear visions of the future. The past decade and a half of benign neglect — with a 20 percent decline, in real dollar terms, of federal support for research and development — must come to an end. America's position as a world leader depends upon the creativity and innovative ability of her citizens. ☐



Yani Batteau

Amory Lovins Guides Hard Technologists

Henry Petroski is a research engineer at Argonne National Laboratory and a free-lance writer.

Like the energy paths he wants the world to take into the next century, his very name — Amory Lovins — is soft, soft as the whispers in this auditorium, where 300 hard technologists are waiting to hear him speak. Relaxing in one of the cushioned theater seats, I think of Cleveland Amory saving Arctic animals, recall my Latin (*amo*, *amas*, *amat*), and remember the flower in the gun barrel on the steps of the Pentagon. Flower power and windmills are soft; modern armies and nuclear power are hard, we would soon be reminded.

Having survived the 1960s, 24-year-old Amory Bloch Lovins resigned in 1971 from his position of junior research fellow at Merton College, Oxford, to become British representative of the environmentalist group Friends of the Earth. Since then he has become probably the most articulate spokesperson for alternatives to the hard-technology approach to future global energy needs.

This morning Mr. Lovins is addressing 300 scientists and engineers — patient technologists, most of whom endured four, five, or more years of postgraduate regimens to earn doctorates in their respective fields — at a national laboratory that is distinguished for its role in advanced nuclear power research and development. This is scores more than turned out to hear Edward Teller in this same room several years ago. Interest in Lovins was correctly anticipated to be so great that admission to the seminar is by reservation only. The event, with questions, will involve about 900 person-hours (almost half a person-year) to give Lovins an opportunity to filibuster and proselytize.

Here are engineers who use heat pumps and solar collectors in energy-efficient houses as best as they know how. Here are physicists who eat, sleep, and breathe thermodynamics and who are convinced that the atom is the only real choice for a future energy source. Here are chemists who know how difficult it is to burn dirty coal cleanly. They all know about synfuels and wind and waves and the other utopian energy resources. But a good half the audience spends at least *some* time on nuclear power research and development.

The subject of the morning is the author's two-year-old book *Soft Energy Paths*, which virtually everyone in the audience has read. Once introduced, Lovins proceeds to lecture for exactly one hour from a seated position in a darkened auditorium. A blunt person would call it rude. Mr. Lovins' face is only partly visible in the light of a projector.

Some of Mr. Lovins' transparencies are very professional, as good as any prepared by the graphic arts department of a Westinghouse or a Mobil to advocate their energy approaches. Like the representatives of those corporations, Mr. Lovins uses color cleverly in his visual aids: red for (hard) nuclear, green for (soft) alternatives.

Most of the viewgraphs are boring, however: too many numbers and examples from the book. The talk is longer than it has to be, but nobody leaves. Lovins has written a powerful and persuasive book; he must have more to say.

Three microphones for the audience are set up in the aisles. Those with questions are instructed to assemble behind the closest mike and await their turns.

"I just finished building a house, and I tried to put as much thought into its energy efficiency as I could. Now I find I don't save all that much energy, and I can't see how to save any more unless I block off the windows completely in winter. Do you think the energy-saving goals you show on your charts are really fair?"

"How much insulation do you have in your ceiling and walls?" asks Lovins.

"R-24."

"You don't have enough. You should have R-36. You live in an energy sieve."

"All the handbooks said R-20 was more than adequate."

"Your windows are only double-glazed. You live in a sieve."

"Double-glazed windows are supposed to be sufficient."

"Don't believe manufacturers' specifications. You built a sieve."

"What do you suggest I do?"

"Two mechanical engineers in Saskatchewan have just written a paper describing a house they built to withstand the Canadian winter. Here is a chart showing the specifications . . ."

"But they have less window area than building codes here allow."

". . . You live in a sieve."

This dialogue is typical of what will follow.

Not until the first and only female questioner, with a hint of belligerence, persists in her skepticism of Lovins' energy path is there another extended interchange of views. In between are a succession of questions generally expressing sympathy for Lovins' argument but admitting doubts that it is realistic.

The questioners by and large are en-

gineers who know the heat transfer properties of liquid sodium and household tap water. They know the technological problems with solar energy and windmills. They know, and they politely confess them to Lovins.

These polite doubters are not sartorially distinguished, of course, and most stand with poor posture, unlike Lovins, who now is moving freely and effectively back and forth in front of the stage as if lecturing to a class on classical thermodynamics.

The Road Not Taken

In *Soft Energy Paths,* Lovins uses Robert Frost's poem, "The Road Not Taken," to symbolize the more desirable soft energy paths chalked out into the grassy future. "The Road Not Taken" might also serve as the explanation of how many of these engineers and scientists came to be where they are this morning. Many simply followed a quiet academic road that, beyond the bend, led them willy-nilly into nuclear power research and development.

For most of these engineers, who are typically in their mid- to late-thirties, as for many people generally, the first fork in the road was encountered in their choices of college majors. If the student was a male in the late 1950s, liked math, and liked to work on cars and model planes, he was likely advised that all roads would be paved with gold in four or five years if he chose engineering.

Professors in the early 1960s with swelling research contracts and grants enticed hoards of young bachelors to stay on the academic road in full-time graduate programs. Most of their students took the path of convenience and least resistance and wrote theses on the same research problems these professors paid them to attack. And those problems were, of course, in the areas funded at the time: defense, aerospace, and nuclear. Sooner or later, the young men were doctors of science and philosophy with esoteric dissertations they would spend the next several years trying to publish and outgrow. Little did they know how difficult that could be, and little did they realize that the more degrees one has, the fewer things one is allowed to do. These Ph.D.'s knew as much about philosophy as most philosophers do about engineering.

Yet the world is made as much of philosophy as of concrete and steel. Energy paths are philosophical constructs of the masters of business administration. The reason a nuclear path, rather than one lined with windmills, has been laid is the same reason that an interstate highway system, rather than a well-maintained railroad network, was the focus of legislative attention for several decades.

Now these humble engineers and their less-humble colleagues, the scientists, stand at the microphones as if waiting to witness at a religious crusade. Although Lovins' talk is uninspired, these hard technologists want to believe, and they offer themselves one after the other to the man in tweeds. He takes their predictable questions and runs with them through appendices to his talk. To this question he produces this viewgraph; to that, another. Time and again he answers their questions with the same hard technological jargon they themselves use at esoteric conferences to defend the arbitrary and belabor the obvious. He manipulates the data as a faith-healer does the cancer of a true believer.

The infantry is looking for alternatives the generals have already rejected. Lovins seems to sense this, and he is really recruiting with his books and his talks. He knows that a lone poet cannot lead the world down the soft-technology path without an army of hard technologists paving the way. It takes the same engineering drudgery to develop a reliable windmill society as a safe nuclear one.

If the engineers and scientists are not as articulate as Lovins, they are at least as sincere. Many are already devoting their best years to soft energy paths by different names, and many others are sharing their time among nuclear fission and fusion and coal and synfuel and solar energy. Among them are the pioneers who are building energy-efficient homes on their drafting boards and their subdivision lots. They are the guerrilla forces Lovins will need to secure a soft energy path through a future where hard technology already claims the right-of-way for its high-voltage transmission lines.

But if Lovins hopes to lead hard technologists along the less-traveled path, he will have to demonstrate more endearing qualities than he does today. He appears to be too hard-nosed about soft technology, and technologists, like others, suspect that people use the most words when they are the least sure of what they are saying. The audience diminishes during the prolonged question-and-answer session. This will not do, for one cannot hope to lead an energy revolution, hard or soft, without a benevolent corps of engineers. ☐

Acts of God: Made Worse by People

The Violent Face of Nature
Kendrick Frazier
New York: Morrow, 1979, $12.95, 386 pp., illustrated, index

Reviewed by James Cornell

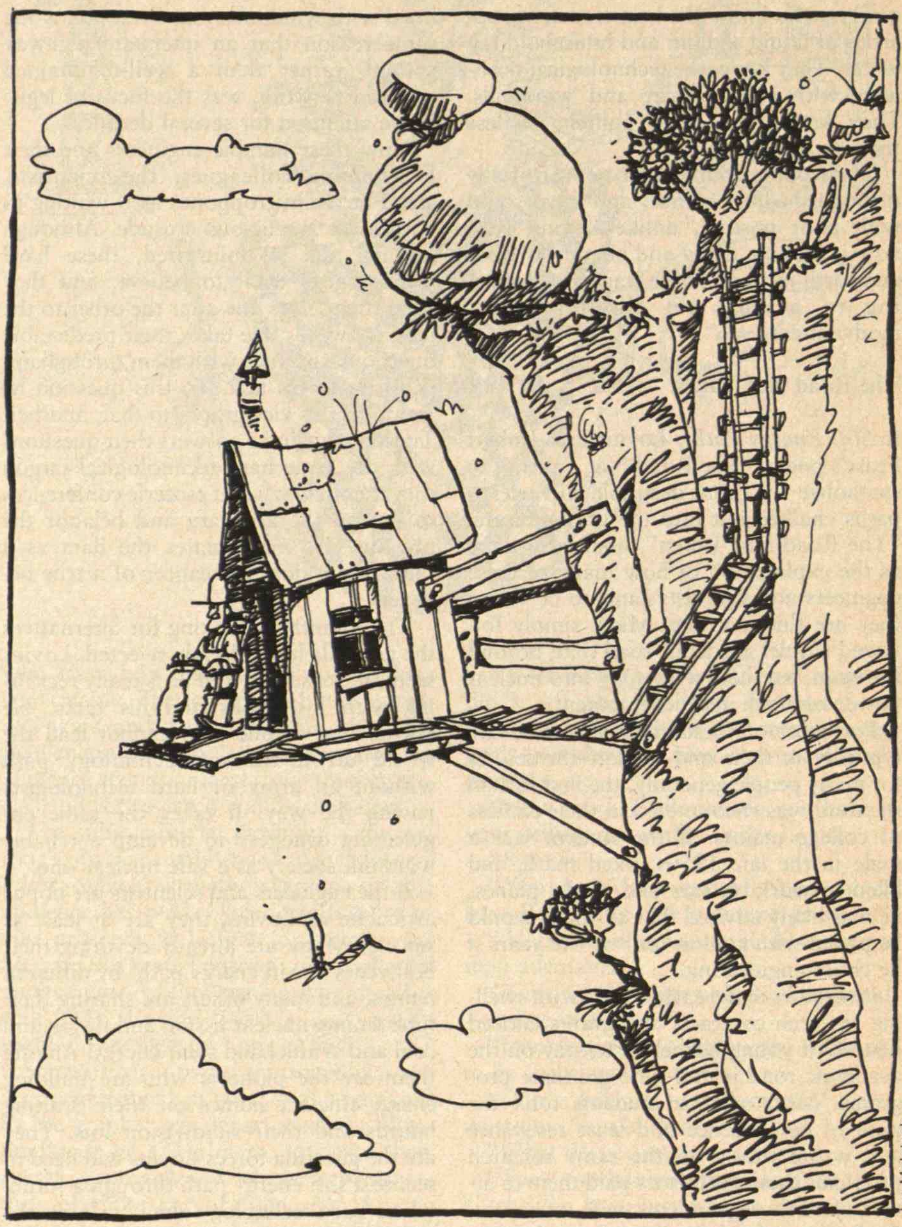
On the night of September 8, 1900, a tropical hurricane struck Galveston, Texas, then a sprawling collection of frame structures built on a low-lying sandspit in the Gulf of Mexico. The next dawn, according to one eyewitness, "about 3,000 homes, nearly half the residential portion of Galveston, were completely swept out of existence. Where 20,000 people lived on the eighth, not a house remained on the ninth."

Over 6,000 people died in Galveston that night, a death toll from a natural disaster unequaled in American history. Yet eight decades later, as the memory of that tragedy dims, Americans are more vulnerable than ever to a host of natural disasters comparable with, or worse than, the Galveston hurricane.

As Kendrick Frazier, former editor of *Science News*, explains in this excellent survey of disaster research and response, our increased vulnerability lies in the belief that we can somehow control the forces of nature. Worse yet, many "technological fixes" designed to reduce hazards have actually increased the potential for catastrophic disasters.

Despite unparalleled human efforts to control nature and prevent disasters, global losses of both life and property continue to rise at an alarming rate. The worldwide cost is now almost $40 billion annually, with some $25 billion lost directly from natural forces and the rest expended in supposedly preventing them. The estimated annual loss of human life is approximately 250,000 people, the equivalent of the total destruction of a city more than twice the size of Cambridge, Mass., every 12 months.

The majority — nearly 95 percent — of the deaths from natural disasters occur among the peoples of so-called developing countries. On the other hand, three-quarters of the annual economic losses are borne by the developed countries. (Of course, in personal terms, the people of poorer countries may actually lose more, for the ratio of loss-to-income may be far greater). Hurricane Agnes of June, 1972, for example, caused over $4.5 billion in damages but took relatively few lives.


Jon McIntosh

Don't Blame Mother Nature

The rise in both material destruction and human suffering is not the result of any increase in the incidence of violent phenomena, however. The occurrence of earthquakes, tornados, and hurricanes has remained fairly constant over the past century. Rather, the rising costs and deaths are due to complex and changing social patterns.

First, the burgeoning world population means there are more people exposed to natural hazards. Moreover, relentless population pressures have pushed people into lands once only marginally acceptable for habitation: floodplains, seismic risk zones, and coastal areas. In the developing countries, this relocation and redistribution has been largely involuntary, the product of want and poverty. But in the U.S. and other industrial nations, population shifts are usually voluntary, spawned by affluence, social mobility, and greed. In both situations, the relocated peoples are usually ignorant of the hazards inherent in their new locations.

"Americans inexperienced with tropical storms have moved in large numbers to hurricane-prone coastal areas of the Atlantic and Gulf coasts," writes Frazier. "Austrian city dwellers are building country homes in the paths of past avalanches, places mountain people know to avoid. Floodplains have been occupied and used for agriculture since the beginning of civilization, but people everywhere, including the United States, are now spreading onto them out of a false sense of security created by structures such as dams and levees."

The relative material wealth of the world has also increased since World War II, and the more a society modernizes, the greater is the social disruption resulting from disaster. An earthquake in today's Mexico City, for example, has the potential for affecting millions more people and destroying literally billions more dollars in property than one a half-century ago. "Disaster potential rises with economic development," notes Frazier. "And the more successful the developmental process is in other respects, the more likely the losses from natural hazards will rise."

Expensive Doesn't Mean Successful

Also rising, although more difficult to quantify, is the cost of society's "adjustment" to disasters; that is, the cost of those measures taken to avoid, reduce, or prevent hazards. These include building flood control systems, financing insurance plans, and establishing storm warning systems, as well as individual efforts such as installing lightning rods and mobile home tie-downs. The unintentional and unpredictable environmental damage done by various engineering works such as dams, drainage systems, and stream rechannelings must also be considered part of the total "disaster adjustment" cost.

Indeed, one wonders if the efforts are worthwhile, for many only increase the disaster potential. The classic case is the federal Flood Control Act of 1936. Intended as a long-term program to reduce the national hazard from flood through construction of dams, levees, and channel improvements, the program cost more than $5 billion. Yet in its first two decades, the total national loss from floods increased.

The reason may be obvious. The construction of large, impressive-looking protection systems only encouraged more people to move into the downstream floodplains to claim land once avoided as too dangerous.

Some technological fixes, of course, have been successful. Many approaches to the earthquake problem — better building design, sensible zoning, careful ground analysis — have proven very effective. But a better balance between the technological solutions and the socioeconomic consequences of hazard reduction is still needed.

The federal government, after four decades of almost total reliance on large engineering programs, has apparently realized this need. New flood control programs place heavier emphasis on disseminating information about flood hazards, giving advice on floodproofing, improving flood warning systems, and researching the kinds of storms that produce flash floods. The National Flood Insurance Plan now makes money available only to those communities that adopt floodplain management programs.

The adoption of such policies at the local level is a slow process, however. Death tolls from floods and flash floods in the last decade were double those of the previous decade. Annual property damage from floods is now about one billion dollars. Over 15,000 communities and recreational areas in the United States are identified as flood-prone. Some 85 percent of all presidential declarations of major disasters are associated with floods, and recovery costs could reach $3.5 billion annually by the year 2000 if floodplain management is not improved.

More frightening, as world population continues to grow and much technology seems only to exacerbate the hazards, the potential for truly great "catastrophes" becomes ever greater. Already in the developing nations, the loss of life from predictable natural hazards, such as the periodic flooding of a river or the seasonal occurrence of tornados and hurricanes, is steadily declining. Yet the losses from single, massive, and extraordinary events, such as the Tangshan earthquake of 1976 (up to 700,000 killed) and the Bangladesh cyclone of 1970 (as many as 1 million killed), are rising sharply.

In the United States, six natural hazards —earthquakes, floods, hurricanes, tornados, tsunamis (giant ocean waves), and volcanic eruptions — are now regarded as having high "catastrophe" potential. For example, more than 70 million Americans now live in two of the nation's highest seismic risk zones.

Of course, natural phenomena are "disasters" only when they affect people. The forces of nature, destructive and deadly as they may be, will continue in the future as they have in the past. It is how we will cope with them that remains uncertain.

"We think our works can protect us against nature," writes Frazier, "when, in fact, they have led us to live less in harmony with the natural world, to remove ourselves from the natural cycles of nature, and to live under a false sense of security that all too often is shattered by sudden natural violence. Our increasingly interdependent world is becoming more susceptible to natural disaster, not less."

There are no easy solutions to the disaster dilemma. However, if history is any guide, whatever solutions are found seem unlikely to be technological alone.

James Cornell is publications manager of the Harvard-Smithsonian Center for Astrophysics and author of The Great International Disaster Book. □

Gee-Whiz Science Writing

Breakthroughs: Astonishing Advances in Your Lifetime in Medicine, Science, and Technology
Charles Panati
Boston: Houghton Mifflin Co., 1980, 306 pp., $12.95

Reviewed by David Perlman

What is one to make of a "science writer" who promises that within this decade — or at the latest the next — almost every disease will be cured, every energy problem will be solved, computers will provide low-cost therapy for our neuroses, and we'll talk through the earth on beams of neutrinos?

If we took all the headlines from the *National Enquirer* and its rivals at the supermarket checkout, we could come up with such a book — and make as much money, probably, as Charles Panati may well collect in royalties and syndication sales from his newest opus.

Panati is a one-time *Newsweek* science writer with an M.S. in physics from Columbia. According to his publisher, he has been "head physicist at RCA" — a title an RCA spokesperson says does not exist. Panati is also the author of *Supersenses*, a book about such paranormal phenomena as psychokinesis and telepathy, which hails their "implications for dramatically reshaping our image of ourselves and our place in the universe."

Eat Chocolate and Get Thin

Physicist though he may be, Panati knows today's popular preoccupations. Two-thirds of his new book is devoted to promises of an incredible assortment of medical breakthroughs in every area of health: mental "imagery" will combat cancer; a vaguely described drug called SQ 14225 will cure hypertension; another, called GK-101, will "spray away" tooth decay; and perfluorooctyl bromide — Panati calls it a "miracle" — will let 60 million obese Americans grow thin by eating chocolate pastry. Each "breakthrough," and the list is endless, rates a page or two of glowing promise.

And what has all this to do with science? Unfortunately very little. Panati's book is an excellent example of how science writing can be perverted — even prostituted — to make a buck. Many of the "miracles" and "breakthroughs" Panati promises may indeed come to pass, and will seem as miraculous to the uninformed as polio vaccine, open-heart surgery, amniocentesis, antibiotics, blood transfusions, x-rays, nuclear energy, television, or even the airplane may have seemed to an earlier lay public.

But the obligation of the science writer goes beyond merely cataloging imminent breakthroughs. Even the most superficial science writer should describe the foundations of breakthroughs and the scientific principles involved, and relate the progress, or failure, of experiments.

Not long ago, two eminent physicians systematically explored the history of science in a limited field where Panati has found scores of miracles and breakthroughs. With more sobriety, the physicians called their findings "the top ten clinical advances in cardiovascular-pulmonary medicine."

The two researchers into research were Julius Comroe, now director emeritus of the University of California's Cardiovascular Research Institute in San Francisco, and the late Robert D. Dripps, once professor of anesthesia and vice-president for health affairs at the University of Pennsylvania. They published their findings in *Science* magazine and in a three-volume report to the National Institutes of Health.

Breakthroughs Demystified

The Comroe-Dripps project took 10 years and was designed to learn how breakthroughs come about. First, they polled 90 leading physicians and surgeons to select the "top ten" advances of the previous 30 years. Open-heart surgery, treatment of hypertension, prevention of polio, chemotherapy for tuberculosis, pacemakers, and intensive care units were among the clinical advances chosen. Next, the two researchers screened more than 6,000 articles in scientific journals, narrowed those to 3,400, and finally enlisted scores of consultants to select 663 key articles for detailed analysis.

What the researchers found was not surprising: "The public, including physicians and many scientists, still equates an important discovery with the name of a single person, e.g., polio vaccine with Salk. However, in every instance we studied, previous work by scores or hundreds of competent scientists was essential to provide the basic knowledge necessary for the clinical advance, usually attributed to one person."

As Comroe and Dripps learned, more than 40 percent of the research absolutely essential to the ten major breakthroughs was wholly unrelated to the actual advance: "Such unrelated research," they noted, "was often unexpected and unpredictable, and usually greatly accelerated advances in many fields."

Yet this study has never been picked up by a sensitive science writer willing to offer the public a truly romantic account of discovery and breakthrough. Consider the "miracle" of the electrocardiogram. Comroe and Dripps date its beginning with a scientific report published in 1672 on experiments with an "electricity machine"; they explore the work of Benjamin Franklin, Luigi Galvani, Alessandro Volta; they take their readers into the discovery of fibrillation; they venture afield to intracellular electrodes and the electrical monitoring of cardiac catheterization. In short, Comroe and Dripps showed how science and discovery really work and how false is the notion of the isolated breakthrough. Panati has done exactly the opposite.

In this day, when technology is suspect and fundamental scientific research wins Golden Fleece Awards, a superficial and sensational book such as Panati's is unnecessary and misleading, and does a disservice to both the public and science.

David Perlman is associate editor and science editor of the San Francisco Chronicle. □

Equality Is Not a Zero-Sum Game

Men and Women of the Corporation
Rosabeth Moss Kanter
New York: Basic Books, 1977, 348 pp.; $13.00

Reviewed by Mary Rowe

By now thousands of America's ablest managers will have read *Men and Women of the Corporation*. Most are probably glad they did, and still more should find it worthwhile. Rosabeth Kanter has combined her own research and insights and the best research of others into a book that is truly important — written without emotion but with deep commitment.

The author adheres firmly to a structuralist view of inequality and its maintenance among employees in corporations. She believes that work roles mold, train, and socialize the worker, especially with respect to the power of the positions held and reasonable expectations of opportunity. Attitudes toward women in business are also strongly affected by the relative proportions of men and women in various positions. (Kanter believes that this argument holds equally for token men in "female occupations," whites in "black occupations," and, in short, for all "nontraditional" people in traditional environments.)

Both men and women need more influence over their work lives; both need to see oppportunities ahead. Kanter convincingly demonstrates that motivation, commitment, loyalty, creativity, flexibility, and productivity are more apparent in people whose jobs include power and possibilities. Since women are disproportionately represented in jobs with little power and less future, it is not surprising to find women with little motivation and commitment, limited creativity, small-minded attitudes, and low productivity. Men in jobs like those typically held by women generally share those unproductive traits, while women tracked into positions of power and mobility come to share high-productivity traits.

The genuineness of equal opportunity at the top, according to Kanter, depends in part on the sex ratio at the top. Tokens are inevitably highly visible, oversupervised, misinterpreted, miscast, overprotected, underprotected, and/or just treated differently. It is impossible, therefore, for a token to be truly "equal." Equal access to jobs is not enough; men and women must be randomly represented throughout an organization for behavioral sex equality. Unfortunately, Kanter does not adequately show that randomizing sex ratios will ultimately serve men as well as women. This is important, since I agree with her view, made explicit elsewhere, that change is best when *everyone* gains, not just women.

Most of Kanter's prescriptions for change seem excellent and workable. However, she omits serious discussion of other, probably necessary innovations: systematic annual salary reviews, the *practical* (as well as symbolic) importance of senior women in top administration, accessible grievance procedures, tuition assistance, and on-the-job training programs for women and men. The omission I most keenly felt was the need for an explicit voicing of commitment to change by the top administration of a corporation.

This book suggests that the inequality of men and women in the corporation derives chiefly from the dead-end roles most women are cast into and the problems of the few token women in nontraditional positions. This suggests that *structure* creates and maintains sex inequality. A complete reversal would cause the same problems for men. Kanter touches only briefly on other theories of inequality. I believe this "role theory" is insufficient to explain all our gender issues.

The Rationale for Inequality

The inequality of men and women has received extraordinary attention for centuries. Why *do* women and men spend their waking hours so differently, with such different rewards?

Religious thinkers have often explained this issue in terms of God's will (or natural law), presuming that the differences are immutable — and right.

Biological explanations abound. Men are stronger and taller and therefore dominant. Men are more aggressive: ditto. Women need to be protected while gestating and nursing and therefore can't compete. The menstruation of women makes them periodically unfit or unreliable. Women know they are "cosmically" important because they can reproduce; men can feel comparably immortal only through great achievement or killing. Women always know who their heirs are; males do not and therefore had to invent a restrictive and monogamous family structure to hobble their females.

Biological differences have also led to social theories. The survival of the species requires inhibition of aggression against the opposite sex; therefore, men and women must not compete. Males also have to bond and create their own turfs, which explains exclusively male groupings. The "sexual insatiability" of women will cause endless warfare among nearby males unless the women are subjugated.

Economic theories add to the picture. Engels and Parsons made clear the continued need for division of labor between men and women that created — and sustained — the family. Survival of families in time of unemployment means women should be sent home to make more jobs for men.

Psychoanalytic theorists have explored sex differences. Boys and girls differ somewhat in some cognitive areas. The fact that male and female infants are cared for principally by females results in irrevocable differences in their abilities to get along with themselves and each other. Our laws, primers, and advertising cast these patterns in concrete.

You probably don't believe all of these theories, perhaps none of them. Moreover, some are losing their bite. We don't want or need dominating, physically aggressive men in corporations. Males and females are more similar than different in most skills and interests. Gestation and nursing are less problematic with a declining birth rate, and babies get more male attention. Laws, primers, and ads are changing slowly. But it's important to note that these theories have been widely believed. Otherwise, how did nonrandom role assignments in companies arise?

Kanter restricts her discussion to men and women in paid work. She eloquently discusses the wife and mother roles and how they affect paid-work roles assigned to women. But inequality between men and women will never disappear in paid work unless it also disappears in unpaid work. If men were randomly distributed in homemaking, child care, volunteer activities, and nurturant paid jobs, more sex discrimination would vanish. "Time-off" policies and part-time work would be more obviously necessary. Equal custody would parallel equal pay. Perhaps our men would live longer, our children be happier, our divorces be fewer, and our families closer and more secure.

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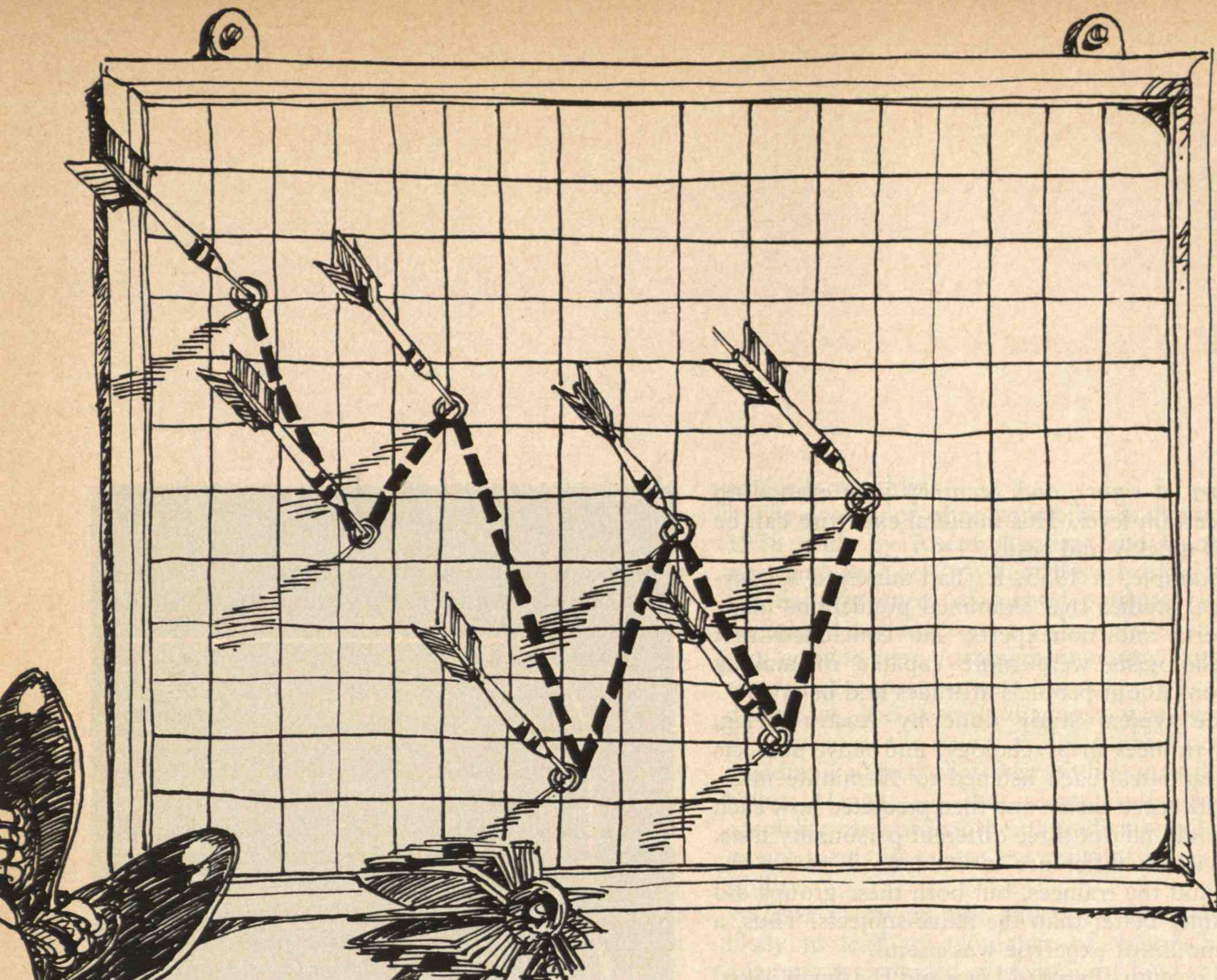
The Seer-Sucker Theory: The Value of Experts in Forecasting

by J. Scott Armstrong

Even if a fortune-teller is called a "consultant," uses sophisticated forecasting techniques, and charges plenty, the resulting predictions may not be any better than those of a student.



Illustrations: Jon McIntosh

People are willing to pay heavily for expert advice. Economists are consulted to tell us how the economy will change, stock analysts are paid large salaries to forecast the earnings of various companies, and political experts command large fees to tell our leaders what the future holds. The available evidence, however, implies that this money is poorly spent. But because few people pay attention to this evidence, I have come up with what I call the "seer-sucker theory": "No matter how much evidence exists that seers do not exist, suckers will pay for the existence of seers."

One would expect experts to have reliable information for predicting change and to be able to utilize the information effectively. However, expertise beyond a minimal level is of little value in forecasting change. This conclusion is both surprising and useful, and its implication is clear: Don't hire the best expert, hire the cheapest expert.

This is not to say that experts have no value — they can contribute in many ways. One particularly useful role of the expert seems to be in assessing a current situation. And although estimates of current status play an important role in forecasting, I will deal only with the role of expertise in forecasting change.

Value of Experts: The Evidence

Many studies have been done on the value of expertise in a given subject area. Most evidence comes from the field of finance, but studies have also been done in psychology, economics, medicine, sports, and sociology. The relationship of accuracy to expertise in a particular field has been measured in various ways — education, experience, reputation, previous success, and self-identification. Expertise, above a very low level, and accuracy are unrelated

(*see chart at right*), and accuracy may even drop after a certain level. This minimal expertise can be obtained quickly and easily.

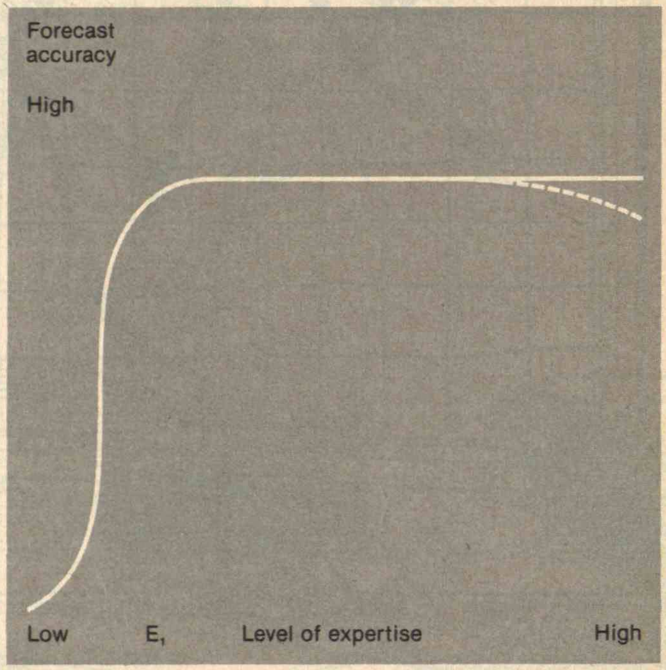
For example, in 1955, R. Taft surveyed 81 psychological studies that examined predictions made by experts and nonexperts. He concluded that nonpsychologists were more capable of making predictions about people's attitudes and behavior.

In one typical study done by Austin Grigg, Ph.D.'s, trainees in psychology, and naive subjects (undergraduates) each listened to 10-minute interviews with three clients and then predicted how each client would fill out three different personality tests. There was no difference in accuracy between the Ph.D.'s and the trainees, but both these groups did significantly better than the naive subjects. Thus, a small amount of expertise was useful.

More recently, Bernard Levy and E. Ulman asked professional mental health workers, students, and people with no mental health experience to distinguish 48 normal people from 48 psychiatric patients by looking at paintings the subjects had done. All the subjects' predictions were significantly better than chance, but here accuracy did not correlate with experience.

The performance of experts and novices in forecasting prices of stocks was first examined by Garfield Cox in 1930. He found no advantage for expertise. In 1933 Alfred Cowles examined 255 editorials by Hamilton, an editor of the *Wall Street Journal* who had gained a reputation for successful forecasting. During the period from 1902 to 1929, Hamilton forecast 90 changes in the market: 45 were correct and 45 were incorrect. Cowles also found that a sample of 20 insurance companies did slightly worse in their investments than the market averages from 1928 to 1931; 16 financial services did slightly worse than the market average from 1928 to 1932; and forecasts in 24 financial publications were slightly worse than the market average over this same period. Other studies, some done as recently as the late 1970s, have reinforced these conclusions.

Ray Johnson and B.F. McNeal had 12 health care professionals — 5 staff psychologists, 6 social workers, and a physician — predict the length of hospital stay for 379 mental patients over an 18-month period. The scores ranged from 63 percent to 86 percent correct. The professionals with more experience in psychology were no more accurate.



Some expertise seems to lead to a higher level of accuracy in forecasting change. Beyond a minimal level, however, additional expertise does not improve accuracy — and there is even some evidence that it may decrease accuracy.

William Avison and Gwynn Nettler examined predictions in nine public opinion polls from 1959 to 1971. Experts, as judged from the amount of schooling, were no better at forecasting change.

In three studies in which "expert forecasts" were more accurate, the gain was small:

☐ A small but statistically significant correlation for a sample of 26 experts in the social and natural sciences in forecasting 123 events in their fields was found by Kaplan, Skogstad, and Girshick in 1950.

☐ Similar findings were obtained in 1976 by Wise, who examined 1,556 predictions published in the United States between 1890 and 1940. For predictions related to social, technological, economic, and

political changes, people with experience in the relevant field seemed to do slightly better than those outside the field.

□ In a 1971 study by Robert Winkler, sportswriters did a little better than graduate students and faculty members in forecasting scores of collegiate and professional football games. The bookmakers' forecasts, in turn, were slightly better than those of the sportswriters.

Overall, the evidence suggests there is little benefit to expertise. And because improved accuracy shows up only in large samples, claims of accuracy by a single expert would seem to be of no practical value. Surprisingly, I could find *no* studies that showed an important advantage for expertise. This evidence does not include every area, however, and further studies may show that the seer-sucker theory cannot be generalized.

Another possibility is that researchers find it easier to publish evidence refuting than confirming the common notion that expertise is useful. However, in light of a 1977 study by Michael Mahoney, this possibility seems remote. Mahoney asked 75 reviewers to referee a paper. Two versions of the paper were presented to randomly selected subsamples of reviewers. The papers differed only in the results: one version had results favoring the common wisdom of the day and the other refuted it. A strong bias was found toward accepting the study that *agreed* with a commonly held hypothesis and rejecting the one that contradicted this hypothesis.

Is Accuracy Irrelevant?

Assume for a moment that the seer-sucker theory is true — that expertise is useless in forecasting change. Is there any rational explanation for why clients continue to purchase worthless information?

One explanation is that the client is not interested in accuracy, but only in avoiding responsibility. A client who calls in the best wizard available avoids blame if the forecasts are inaccurate. The evasion of responsibility is one possible explanation for why stock market investors continue to purchase expert advice in spite of overwhelming evidence that such advice is worthless.

The avoidance of responsibility is illustrated in a 1978 study by Joseph Cocozza and Henry Steadman. In New York, psychiatrists are asked to predict the dangerousness of mental patients — patients diagnosed as dangerous are then placed in involuntary confinement. Although numerous studies have shown that psychiatrists cannot predict who is dangerous, the expert's diagnosis was accepted by 87 percent of the courts in this study. Cocozza and Steadman suggest that their finding may illustrate a belief in magic — that secret knowledge of the specialist can control the unpredictable. The expert advice seems to relieve the court of further responsibility.

Cases involving risk and uncertainty seem most likely to lead to avoidance of responsibility. An example is provided in a study of long-range forecasts of bed requirements for six Michigan community hospitals. Clients were satisfied only when the forecasts matched their preconceptions. When differences arose, the hospital administrators followed their preconceptions anyway, ignoring the advice of experts. The preconceived forecasts exceeded the experts' forecasts for five of the six hospitals and led to decisions that resulted in a 50 percent oversupply of beds.

Ineffective Learning by Seers

"Expertise . . . breeds an inability to accept new views." — Laski (1930)

The continued inclination for people to consult expert advice has been the subject of much study. In 1948 B.F. Skinner experimented with a pigeon in a cage. Food was given to the pigeon on a random time schedule. What happened? The bird concluded that a counterclockwise movement produced the food since it was doing that the first time food appeared. It repeated this behavior whenever it was hungry. This initial learning proved to be highly resistant to change, even though it had absolutely nothing to do with the appearance of food.

In 1958 Lloyd Strickland found that people do a

good job of simulating pigeons. He had subjects act as managers of two subordinates whom I will call Stan and Ned. The manager could see Stan's work and communicate with him easily. Communication with Ned was poor. However, both Stan and Ned produced the same amount and quality of work. The manager trusted Ned but thought Stan required constant supervision — he had concluded that his management efforts were responsible for Stan's output.

In a more recent study, Daniel Kahneman and Amos Tversky discussed a flight school training program in which trainers adopted a recommendation from psychologists that they use only positive reinforcement — they praised successful work and said nothing otherwise. After a time the instructors concluded that positive reinforcement did not work; when they praised someone for successfully completing a series of complex maneuvers, the trainee would often do worse the next time. That happens because learning involves mistakes. A student cannot consistently perform well — an exceptionally good trial will usually be followed by a more average trial, and conversely for an exceptionally poor trial. The flight school trainers noticed this phenomenon and attributed it to their actions. As a result, they "learned" that what works is punishment for bad behavior (because the odds are that the next trial will be better). Rewards, they concluded, just lead to overconfidence of the learner.

In these studies, subjects first are assuming that their own actions control the situation. (This effect shows up even in studies of gamblers.) Second, they are looking for evidence to support their hypotheses; that is, they are looking for confirming evidence and avoiding disconfirming evidence. This latter phenomenon can occur even in the absence of any notion of control or emotional involvement, as shown in the following experiment.

P.C. Wason presented subjects with a three-number sequence: 2,4,6. The subjects were told that this sequence had been generated by a rule that the experimenter had in his head. The subjects were then asked to learn the rule by generating additional three-number sequences (e.g., 8,10,12). After each try, the experimenter told the subject if the new sequence agreed with the rule. The subject could generate as many three-number sequences as she wished; when she felt confident of the rule, she wrote it down.

The correct rule was "three numbers in increasing order of magnitude," that is, $a < b < c$. Despite its simplicity, only about 25 percent of the people tested discovered the correct rule. Subjects usually selected a hypothesis (e.g., "add two to each successive number") and looked only for evidence to confirm this hypothesis — they did not attempt to refute it. In other words, most people refuse even to entertain the possibility that they are wrong!

The story gets worse. Subjects who wrote the wrong rule were allowed to try again — to generate additional sets of numbers to obtain more evidence. About half these subjects continued to search for confirmation for the rule they had been told was wrong.

It is not clear whether subjects failed to accept disconfirming evidence because they were unable or because they were unwilling. When asked how they would find out whether their hypothesis was wrong, however, few recognized the need to look for disconfirming evidence by generating a sequence of numbers inconsistent with their hypothesis.

Is Wason correct that people avoid disconfirming evidence? If you believe "yes," I can present confirming evidence to make you happy. If you believe "no," I can give a prima facie argument and you may get upset at me. So I leave it to you to seek disconfirming evidence.

The evidence just cited, however, implies why one might expect expertise to reduce accuracy (as suggested by the dotted line in the chart on page 20). The greater one's feeling of expertise, the less likely that disconfirming evidence will be used. Loren Chapman and J.P. Chapman studied this issue by asking 32 subjects with high expertise to examine data from homosexual and heterosexual subjects. The information was contrived so that there were no relationships among variables that previous literature had found to be irrelevant. Nevertheless, the practicing clinicians saw the rela-

tionships that they expected to see (which, incidentally, were the same invalid relationships expected by a group of nonexperts), and they had great difficulty seeing valid relationships even when these were dramatic. In a related study, George Strickler found that although people with high expertise rejected valid disconfirming evidence, subjects with much less expertise improved their accuracy by using disconfirming evidence.

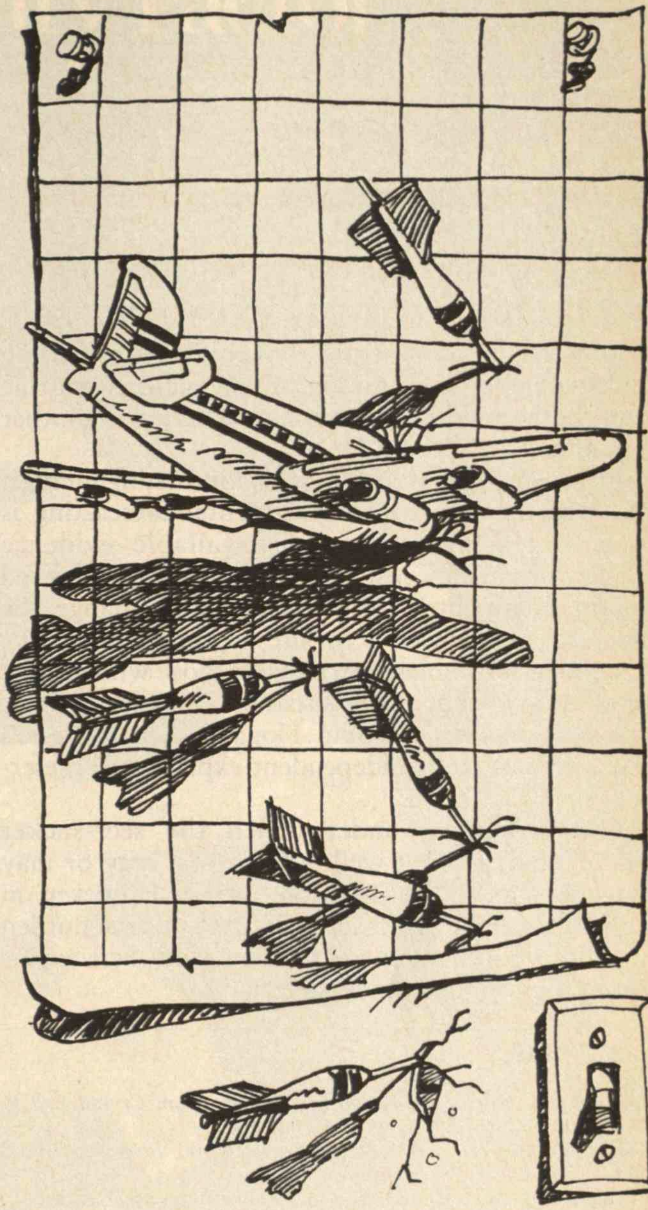
Salvaging the Expert

The seer-sucker theory implies that clients will continue to depend upon experts. It is important, then, to consider whether experts can improve their ability to forecast change. The prospects are not good; evidence reviewed by Nisbett and Wilson shows that experts are often unaware of how they make judgments and predictions. For example, a 1964 study by E.C. Webster showed that decisions in employment interviews are typically made in the first 30 seconds of the interview. Moreover, the reasons for the decision are not usually understood by the interviewer.

Still, there is hope. Detailed instructions for improving judgmental forecasting are provided by Hillel Einhorn and Robin Hogarth, and additional suggestions are given in my book, *Long-Range Forecasting*. Probably the key is to make an active search for disconfirming evidence. Without this search, disconfirming evidence is often ignored, misinterpreted, or misused.

The advice to seek disconfirming evidence is not new — it is the principle behind "objective" scientific experiments. Unfortunately, it is not often used even by scientists, and training does not seem to help. In a study using Wason's 2-4-6 problem, Mahoney and DeMonbreun found that the aversion to disconfirming evidence is just as prevalent among physical scientists as it is among psychologists.

I have recommended an old solution for the problem of finding disconfirming evidence. The method of multiple hypotheses, first suggested by T.C. Chamberlin in 1890, can be used to change one's role from advocate of a particular belief to arbiter



Three Rules for Airline Forecasters

Predicting the future is always difficult, but in a business like the airline industry, which is particularly sensitive to the economic climate as well as a multitude of other factors, the job can be well nigh impossible.

Yet forecasting in the airline industry is vitally important (for example, new airplanes must be ordered years in advance), so the airlines put lots of emphasis on the business of making forecasts. Needless to say, such predictions are often wrong.

Planners in other fields may find comfort in the three rules for forecasting that have been accepted as folk wisdom in the airline industry. As with most folk wisdom, their originator is unknown.

☐ Rule 1. Don't forecast.

☐ Rule 2. If you must forecast, collect your paycheck before you forecast.

☐ Rule 3. If you've done the first two and still must forecast, just don't put dates on the horizontal axis. — *K.R.* ☐

among various competing viewpoints. When using multiple hypotheses, disconfirming evidence for one hypothesis could be confirming evidence for another hypothesis.

Although experts are poor at forecasting change, this does not mean that judgmental forecasting is useless. However, since all available evidence suggests that expertise beyond an easily achieved minimum is of little value in forecasting change, the most obvious advice is to hire inexpensive experts. Also, look for unbiased experts — those who are not actually involved in the situation. Finally, there is safety in numbers. Robin Hogarth has suggested using at least three independent experts and preferably six to ten!

The conditions under which the seer-sucker theory holds are not well known — it may or may not apply to all areas of forecasting. However, in view of the evidence, it seems wise to put the burden of proof upon the experts to show that their expertise in a given area is valuable.

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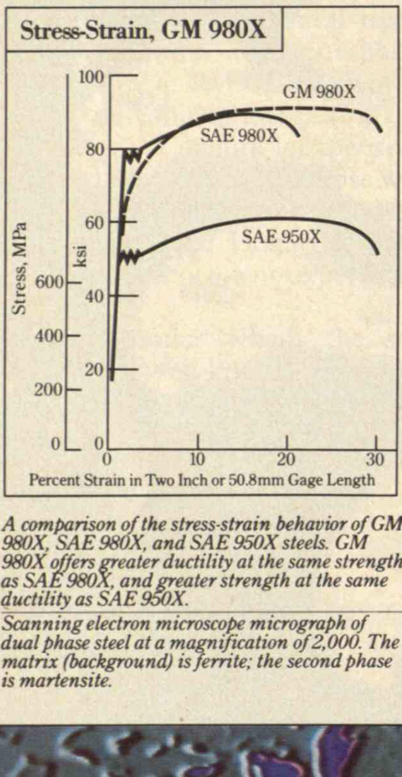
J. Scott Armstrong is himself an expert on forecasting methods. He holds a Ph.D. from M.I.T.'s Sloan School of Management and is currently an associate professor at the Wharton School, University of Pennsylvania. His publications include the topics of marketing research, forecasting, educational methods, and social responsibility in management. His book, *Long-Range Forecasting: From Crystal Ball to Computer*, was published by Wiley-Interscience in 1978.


The Ductility Factor

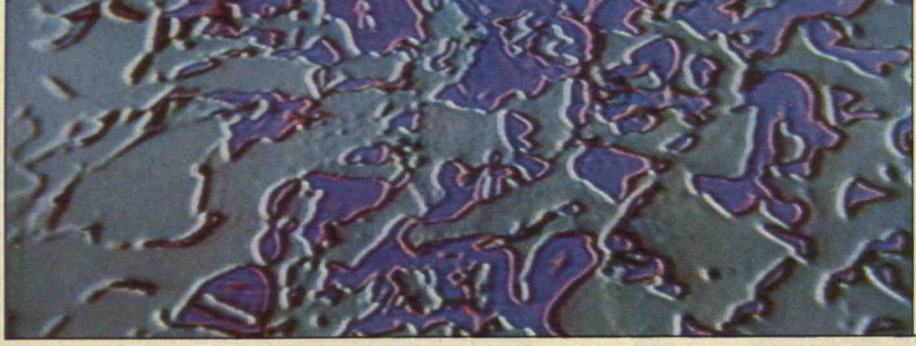
The Ductility Factor

The use of high strength, low alloy steel has been severely limited, due to its low ductility. Now, a simple heat treating and controlled cooling process, developed at the General Motors Research Laboratories, has successfully enhanced formability properties without sacrificing strength.



A comparison of the stress-strain behavior of GM 980X, SAE 980X, and SAE 950X steels. GM 980X offers greater ductility at the same strength as SAE 980X, and greater strength at the same ductility as SAE 950X.

Scanning electron microscope micrograph of dual phase steel at a magnification of 2,000. The matrix (background) is ferrite; the second phase is martensite.



For some time, automotive engineers and designers have been faced with the challenge of building cars light enough to get good gas mileage, but still roomy enough to comfortably transport four or five passengers. One technique which has proved fruitful is materials substitution.

Lighter materials, such as aluminum alloys and plastics and high strength, low alloy steels (HSLA), are being phased into new vehicle designs to replace certain plain carbon steel components. Each, though, has displayed inherent problems which limit its utilization.

Unlike plastics and aluminum, however, HSLA steels have the same density as plain carbon steel. Weight reduction is achieved because thinner sections (less volume) can be used to carry the same load. Since the formability (ductility) of most high strength steels is poor, though, it has only been possible to form simple shapes from it. This has severely limited the widespread use of HSLA steels (such as SAE 980X) for auto components. New hope for the increased utilization of HSLA steel has arisen, however, with the development of a new dual-phase steel, GM 980X, at the General Motors Research Laboratories.

General Motors is not in the steel business, and GM 980X is not a brand of steel. GM 980X is the designation for a type of steel displaying mechanical properties similar to those of the samples first formulated at the General Motors Research Laboratories. "GM" in the designation indicates that the steel is a variation of the conventional SAE 980X grade. In the standard SAE system for material identification, "9" designates that the steel is HSLA. "80" is the nominal yield strength of the metal in thousands of pounds per square inch. The "X" denotes a micro-alloyed steel—one containing on the order of 0.1% of other metals such as vanadium, columbium, titanium, or zirconium as a strengthening agent.

GM 980X displays the same strength, after strain hardening, as SAE 980X steel, but has far more ductility. This characteristic allows it to be formed into various complex shapes which were previously thought to be impossible with HSLA steels. The superior formability of GM 980X has substantially increased the utilization of HSLA steel in the manufacturing of automotive components such as wheel discs and rims, bumper face bars and reinforcements, control arms, and steering coupling reinforcements.

Dr. M.S. Rashid, discoverer of

the technique to make GM 980X steel, comments, "I was working on another project using HSLA steel, when I noticed that if SAE 980X steel is heated above its eutectoid temperature (the temperature at which the crystalline structure of metal is transformed) for a few minutes, and cooled under controlled conditions, the steel developed significantly higher ductility and strain-hardening characteristics, with no reduction in tensile strength."

FURTHER experiments proved that the key variables to make GM 980X are steel chemistry, heating time and temperature, and the rate at which the steel is cooled. Specimens of SAE 980X were heated in a neutral salt bath, then cooled to room temperature with cooling rates ranging from 5° to 14°C/sec. (9° to 26°F/sec.). Dr. Rashid notes, "We found that the maximum total elongation resulted when the cooling rate was 9°C/sec. (16°F), and the lowest total elongation resulted from the highest cooling rate (14°C or 26°F/sec.)."

GM 980X steel has a high strain-hardening coefficient or n value, accompanied by a large total elongation. The n value gives a measure of the ability of the metal to distribute strain. The higher the n value, the more uniform the strain distribution and the greater the resistance of the metal to necking (localized hour-glass-shaped thinning that stretched metals display just prior to breaking). Tests have proved that GM 980X distributes strain more uniformly than SAE 980X, has a greater resistance to necking, and thus has far superior formability.

"The superior formability of GM 980X compared to SAE 980X steel appears to depend on the nature of two microstructural constituents, a ferrite matrix (the principal microstructural component) with a very high strain-hardening coefficient, and a deformable martensite (the other crystalline structure) phase. In the SAE 980X, failure occurs after the ferrite becomes highly strained, but when the GM 980X ferrite is highly strained, strain is apparently transferred to the martensite phase, and it also deforms.

"Therefore, voids leading to failure do not form until after more extensive deformation has occurred and the martensite phase is also highly strained. Obviously, the exact nature of these constituents must be important, and any variations in the nature of these constituents could influence formability. This is the subject of ongoing research."

Dr. Rashid's discovery represents a significant breakthrough in the area of steel development. His findings have opened the door to a new class of materials and have completely disproved the commonly held belief that high strength steel is not a practical material for extensive automotive application. "At GM, we've done what was previously thought to be impossible," says Dr. Rashid, "and now we're hard at work to find an even stronger and more ductile steel to meet the needs of the future."

THE MAN BEHIND THE WORK

M.S. Rashid is a Senior Research Engineer in the Metallurgy Department at the General Motors Research Laboratories. He was born in the city of Vellore in Tamil Nadu (Madras), India, and attended the College of Engineering at the University of Madras–Guindy. He came to the United States in 1963 and was awarded a Ph.D. in Metallurgical Engineering from the University of Illinois at Urbana-Champaign in 1969.

After a three year Post-Doctoral Fellowship at Iowa State University, he joined the staff of the General Motors Research Laboratories.

Dr. Rashid is continuing his investigations into the development of even more ductile high strength, low alloy steels. When not in the lab, he enjoys relaxing by playing tennis and racquetball with his wife, Kulsum.

How Prometheus Came to Be Bound: Nuclear Regulation in America

by
Michael W. Golay

Adversarial participatory regulation is among the factors that have brought the U.S. nuclear industry to its knees. Significant changes are suggested by the European experience.

Even before the events at Three Mile Island in 1979, many people regarded the way in which nuclear power is regulated as its major problem in the United States. That perception has been strengthened by the investigations and turmoil following that accident. And the perception is likely to remain valid into the distant future because of the failure of our institutions and society to address the essentially inconsistent and irrational structure of the nuclear safety regulatory system.

The various commissions that studied the Three Mile Island accident have focused primarily on the technical issues of who did what when, how procedures should be made more efficient to prevent future accidents, how safety standards should be changed, and how the management system of the Nuclear Regulatory Commission (NRC) should be restructured. None of these investigations has considered the accident in the context of the political situation of nuclear power in the United States, with the technical issues being facets of a larger problem.

There is wide agreement that the way in which nuclear power is now regulated in the United States is harmful to the public good. At one extreme, this view is expressed by those who fear that nuclear power subjects the public to severe and unjustified risks. At the other extreme, this view is taken by those who fear that the economic health of the nation is grievously endangered by the imminent regulatory extinction of nuclear power as an energy option. The latter group holds that the American way of regulating nuclear power inherently contains a strong deterrent to its use, and that this disincentive is largely independent of the technology's safety. If this is correct, the implications of the economic benefits foregone because of the needless suppression of nuclear technology are important.

I attempted with two associates, I.I. Saragossi and J.M. Willefert, to understand these issues. Our work took two approaches:

☐ An examination of the structure and history of nuclear safety regulation in the United States.

☐ An examination of the nuclear safety regulatory systems in other countries, to determine whether problems in the management of nuclear power have arisen in industrialized, technically advanced countries culturally similar to the United States.

Wanted: Political Guides and Restraints

The nuclear regulatory system in the U.S. includes many agencies at many governmental levels. Notable among them are the federal Nuclear Regulatory Commission and the Environmental Protection Agency (EPA), state public utility commissions and environmental quality agencies, and local zoning and transportation authorities. These agencies deal with such diverse issues as public and occupational health protection, environmental quality, land use, and financial regulation of monopoly utility com-

panies. In general, each of these actors is independent and without obligation to respect the jurisdiction and commitments of the others; this fact alone assures a regulatory situation in which it is virtually impossible to predict the final decisions that will be rendered or when they will be made.

To simplify analysis of this problem, we will focus primarily upon the licensing reviews of the Nuclear Regulatory Commission. The licensing review is a two-step process involving a construction permit that is required before power station construction can begin and an operating license that is required before a completed power station can begin operation. Though there are differences in the technical issues for each license, the procedures are structurally similar. We assume the technical reviews are conducted competently and have the proper scope, although that has not always been the case.

Three parallel reviews are required for the construction permit, involving antitrust, safety, and environmental issues. Two reviews — of safety and environmental issues — are completed before an operating license is issued. The antitrust review is rarely important in affecting power station licensing or construction. The safety review is concerned with such topics as the adequacy of systems designed to handle accidents and routine radioactive releases and the extent of the operator's emergency plans. The review is based on material submitted by the license applicant, and in evaluating it the NRC is charged by Congress to protect "the public health and safety." No explicit guidance is provided to the commission on what constitutes an adequate level of protection or whether economic factors may be taken into account in determining the protection criteria. The NRC is thus given the task of deciding what level of protection is adequate — essentially a social decision rather than a technical one. The failure of the political system (i.e., Congress) to provide clear guidance has left the decision by default to a trial-and-error process in which the NRC's decisions are reviewed and frequently modified by the federal courts. The result is a public-health protection system that is inconsistent, uncoordinated, costly, and undemocratic. Vox populi enters the process only through efforts to challenge regulatory decisions, usually by political pressure groups. The will of the majority is never expressed directly regarding the appropriate level of health protection.

The environmental review was first required in 1971, when a federal appeals court ruled that the Atomic Energy Commission (AEC, predecessor of the NRC) must under the National Environmental Policy Act of 1969 (NEPA) prepare an environmental impact statement for each power station licensed to detail the environmental consequences of its construction and operation. The court directed that the environmental impact statement be used "to ensure that the optimally beneficial decision" would be made, and a cost-benefit analysis for the proposed power station was required. This latter requirement is ambiguous enough to provide employment for generations of economists and political scientists (as well as engineers).

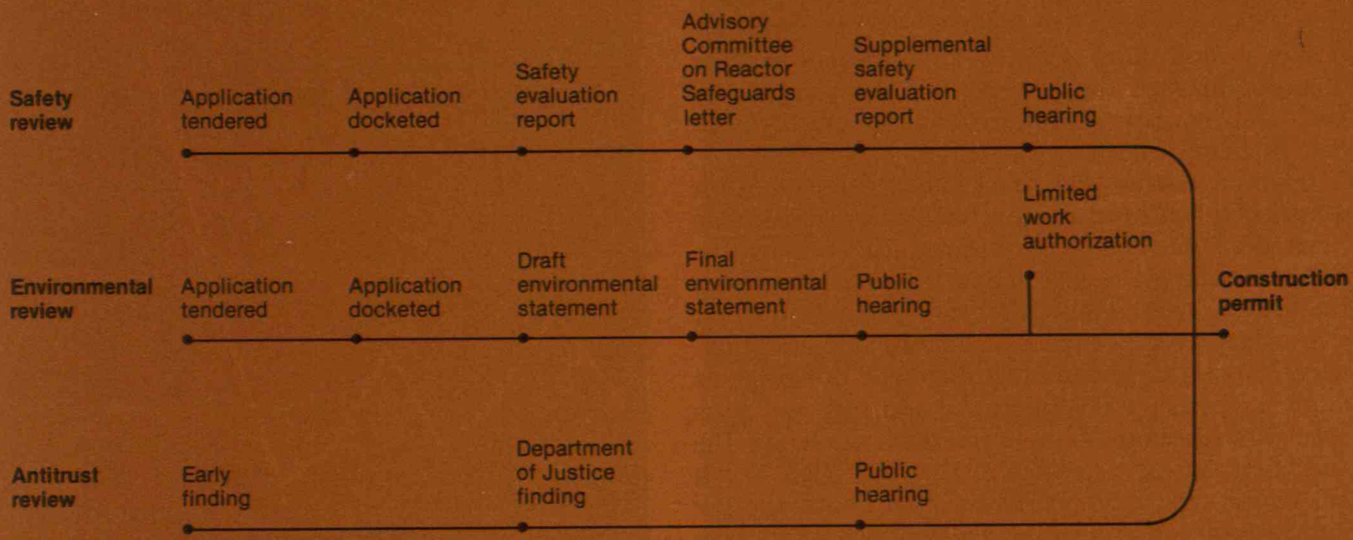
Given the ambiguity of the safety and environmental criteria, it should be no surprise that the licensing of U.S. nuclear stations has become a forum for political conflict. Who are the typical protagonists, and what are their goals?

□ *The applicants* are concerned with obtaining a license speedily with as few design modifications as possible. They also desire that the licensing procedures be thorough and thoroughly documented so that the license cannot be successfully challenged in subsequent litigation.

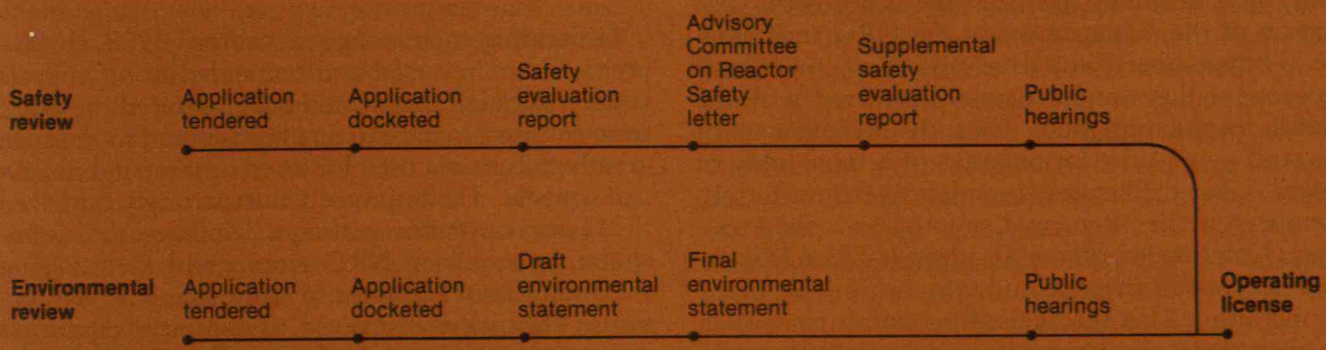
□ *The Nuclear Regulatory Commission* and its Atomic Safety and Licensing Board (ASLB) share the applicants' interests in thoroughness, since reversal of ASLB decisions implies a reprimand. This congruence of goals with applicants leads to the frequent criticism that the regulator has been captured by the regulated to the detriment of the public interest. However, it is important to note that this situation does not arise until the ASLB decision is rendered.

□ *Intervenors* may have a variety of goals, ranging from concern over a narrow technical issue to opposition to nuclear power under any circumstances. Much of the frustration associated with public participation in nuclear plant licensing procedures arises because the procedures were formulated to ensure fairness in considering the narrow technical issues that inevitably arise, while the interests of antinuclear activists were thought to be beyond the scope of the licensing process. However, it has turned out that our political system offers few avenues as effective to those who oppose nuclear power as intervention in the licensing process, and opponents of nuclear power use specific technical objections to the design of a particular station as surrogates for affecting much broader issues. This opportunity is used in two ways: to achieve changes in the criteria of regulation by a court ruling that reverses a previous regulatory agency action; and,

To begin construction



To begin operation

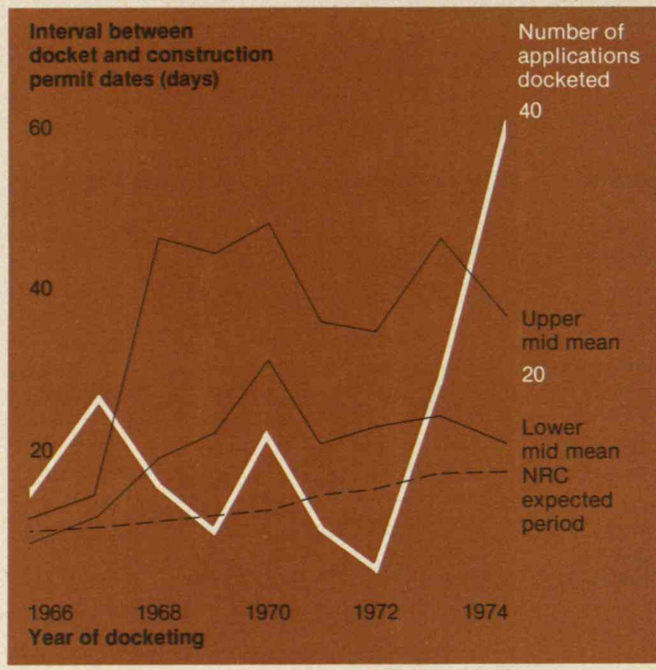


Construction permits for nuclear reactors are issued in the U.S. after a three-track process has been fulfilled. There are: 1) a safety review; 2) an environmental review under which the Nuclear Regulatory Commission is required to set environmental costs against benefits culminating in approval from the three-member Atomic Safety and Licensing Board; and 3) an antitrust study to show that the new reactor will not unfairly affect the ability to provide service of various members of the utility industry. As a nuclear plant nears completion, it approaches a second regulatory hurdle, the operating license review. The basic questions are designed to assure that the new plant has been built according to the conditions of the construction permit, that it will be operated safely, and that its environmental impact will be as low as specified. But even at this late stage, it is necessary for the utility to again prove that the plant's output is needed. With these conditions satisfied, the Nuclear Regulatory Commission grants an operating license and the plant is authorized to begin generating power.

more importantly, by inflicting financial pain on the individual license applicant. For a utility applicant committed to completing a specific nuclear project, this delay and even the requirement of expensive design modifications is not usually sufficient to cause abandonment of the project, but the prospect of such discomfort can have a "chilling" effect on future nuclear projects.

Intervenors who wish to change or delay plans for a nuclear plant must demonstrate a flaw in the way that their concerns have been considered by the NRC in issuing a license. Thus, their goal is to have the hearing record show that they raised important issues that were not given fair and complete attention. This leads obviously to the tactic of raising as many issues as possible in public hearings, and gives special advantage to actions that challenge the decision-making criteria used by the NRC. Such challenges (for example, a question about the environmental impacts of the nuclear fuel cycle) have been especially useful vehicles for licensing delay, since neither the NRC license review staff nor the ASLB is empowered to change such criteria in individual plant licensing actions.

For participants who lose their cases as a result of ASLB decisions, there are several levels of appeal: the Atomic Safety and Licensing Appeals Board, then the five-member Nuclear Regulatory Commission itself, and finally the various levels of federal courts — ultimately the U.S. Supreme Court. This function of the commissioners in reviewing lower-level NRC decisions has been the basis of the separation of the management of the NRC staff from the commissioners' impartial review of lower-level decisions if they were intimately involved with the staff in formulating them. Thus, the management of the staff — and the formulation of a large body of policy — has deliberately been left to the staff itself. Members of the "Kemeny Commission" (the President's Commission on the Accident at Three Mile Island) expressed surprise and criticism of this mode of operation. This reaction seems unfair since such an operational structure had been in place throughout seven presidential administrations since the origins of the AEC, with repeated sanction by Congress and the courts. (The NRC has also been criticized for being poorly prepared to respond to the Three Mile Island accident as the lead governmental agency. Then, as today, it had no clear legal authority for such a role, which is reserved for the states, many of which are unprepared to handle it; the NRC was organized for an entirely different function.)



The "normal" time for a utility between application for and granting of a construction permit for a new nuclear power plant is specified by the Nuclear Regulatory Commission as 22 months. But most utilities have experienced delays, and some have been involved in redesign work and litigation for as long as four years before receiving permits to begin construction. The chart shows only delays *not* mandated by the utilities themselves because of changed demand forecasts or financial arrangements. The data are from a survey by the author and his associates of all utilities having lead responsibility for large nuclear projects.

In deciding such an appeal in April 1979, the Supreme Court reversed and remanded to an appeals court a decision that would have required the NRC to re-examine many existing licenses and to broaden greatly the criteria used for its environmental impact assessments. The Supreme Court strongly criticized the lower courts for creating a "Kafkaesque" atmosphere in reviewing NRC actions and for usurping the authority of Congress to set criteria for NRC actions. They were instructed to confine their future interest to questions of whether the NRC had correctly followed its own licensing procedures.

Whether this ruling will affect the use of licensing intervention as a tactic by opponents of nuclear power is unclear. However, since that decision, at least one nuclear plant licensing challenge — to the Seabrook station — has been dismissed in federal courts, and this tactic may well be used less frequently by intervenors.

Foreign Regulatory Systems

How does this pattern of nuclear regulation differ in foreign countries, and how have these different regulatory systems affected the development of nuclear power overseas? Can the U.S. draw lessons from such systems and experiences?

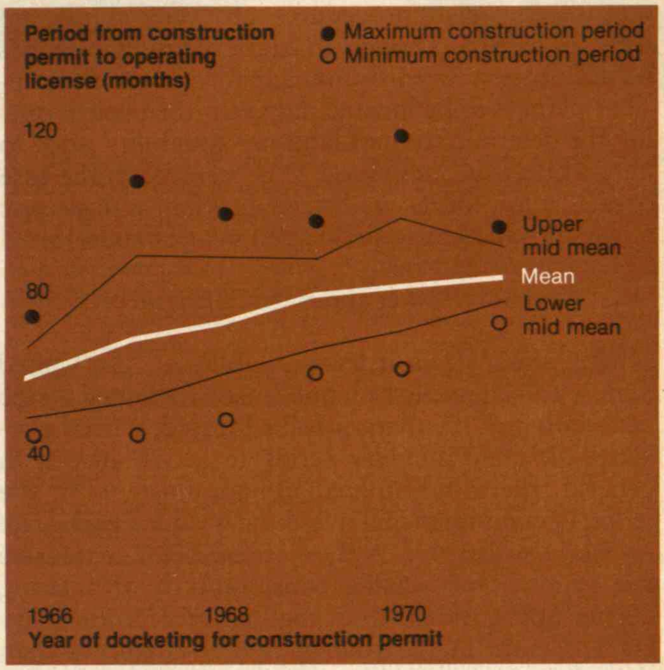
To answer these questions, we examined regulatory systems in England, France, Sweden, and West Germany. We did not attempt to evaluate the public safety and environmental protection criteria used for decision making in these countries; thus, no information is provided about whether these four systems result in the construction of safer or more environmentally acceptable nuclear power plants. Although the substance of the technical reviews required in the regulatory process is essentially the same as in the United States, there are substantially different safety criteria and some different safety systems in each country. English reactors, for example, are of basically different design and are not easily compared with American reactors.

The table summarizing the characteristics of the nuclear utility and regulatory systems in each country (*see page 36*) shows that the systems of the U.S. and Sweden are similar, while those of the remaining countries are not. Sweden, West Germany, and the United States have, in effect, nuclear moratoria, while France and England do not.

In Sweden, separate construction and operation licenses are issued, as in the United States. The remaining countries use incremental permits issued at several stages of power plant construction, beginning with site preparation work.

As in the United States, the most important license in each of these countries is that permitting construction to begin. In most cases, this is the point of no return on a nuclear project, and in all the countries this license receives the greatest attention.

In each country, issuance of the first construction license is usually but not always preceded by a legislative-type public hearing concerning the appropriateness of the proposed site for a nuclear power station. Relevant documents are provided by the government for public review, interested parties are permitted to state their views and the evidence supporting them, and the hearing officer may question them as he or she wishes. However, in some important respects, these hearings are different from those in the United States: there are no intervenors, cross-examination of the participants by anyone



The time required to build a nuclear power plant has been increasing steadily since 1966, due in part to the increasing complexity of the machines being designed for the 1970s and in part to the increasing difficulty of fulfilling regulatory requirements and responding to intervenors' challenges. The spread of times above and below the mean indicates that reactor construction schedules are "significantly uncertain," and this uncertainty serves to make reactors harder to finance and more expensive to build than they should be.

other than the hearing officer is not permitted, and the hearing does not lead directly to a decision on whether the power station is to be built. Rather, the hearing typically results in a recommendation to the appropriate ministry regarding the suitability of the site. Since no decision is made solely and immediately as a consequence of the hearing, no members of the public can challenge the hearing in terms of injury to their immediate personal interests. Indeed, an important aspect of each of the European systems is that individuals who object to a regulatory action are without effective avenues for participating in the licensing process — there is relatively little recourse short of changing the composition of the current government. (*See "Public Participation in Technological Decisions: Reality or Grand Illusion?" by Dorothy Nelkin and Michael Pollak, August/September 1979, p. 54.*)

This in fact happened in Sweden in 1976, resulting in the current Swedish moratorium on new nuclear plants. Except for omission of the American public hearing and absence of U.S. post-licensing

appeals, Swedish procedures are very similar to those in the U.S. Though an aggrieved individual has no recourse, a Swedish municipality in which a nuclear plant is to be located may veto the project during the determination of land-use suitability prior to nuclear licensing activities. This occurred in the case of a reactor for both district heating and electric power production to be located near Stockholm.

West Germany: Enter the Referee-Engineer

West Germany is a federal republic like the United States, and all nuclear plant licenses are issued by the state in which the plant is to be located, with the responsible state ministry acting in accordance with general criteria formulated and administered by the federal government. To avoid the need for each state to establish its own replica of the NRC, extensive use is made of outside consultants in evaluating license applications; thus, regulatory decision makers are more in the role of referee-engineers than their American counterparts when examining both a design submitted by the utility applicant and an independent criticism of the design. Relieved of the responsibility to defend the correctness of a design that they have approved (in the event that new information should show their decisions to be unjustified), regulators act more as impartial judges than in the United States. This permits them to take somewhat more risks than their American counterparts. This arrangement is of special interest in light of proposals for transferring major responsibility for the environmental aspects of nuclear power licensing in the United States from the federal government to the states, most of which would currently be incompetent to undertake such a responsibility.

France: Nuclear Power in the National Plan

In France, nuclear plant licensing is a cooperative activity involving the national government (mainly the Service Central de Suréte des Installations Nucléaires and the Commissariat à l'Energie Atomique), the national state-owned utility company, Electricité de France, and the sole French vendor of nuclear power systems, Framatome. Licensing is viewed as an integral part of the well-coordinated national effort to fulfill clearly formulated national economic goals, subject to public health and environmental protection constraints. The public is seen as incompetent to participate in the licensing of individual plants and is excluded from these proceedings. Indeed, reports on the performance of the various safety systems and the names of the persons involved in licensing activities are not public information. Licensing activities are concerned exclusively with narrowly defined technical isues; broader political questions, such as the need for new power supplies and the levels of acceptable health risks, are resolved independently at higher levels of the national government.

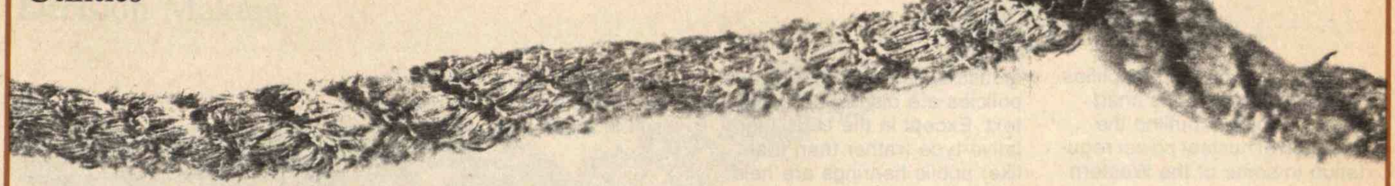
Of the countries we studied, only in England does the nuclear power industry claim to have essentially no sense of being opposed by many angry people. The national utility, the Central Electric Generating Board, now expects long-term excess capacity, and few new nuclear plants are being ordered; but opposition to nuclear power is not cited as a factor in this decision.

Incremental licensing activities proceed as continuing negotiations, shielded from public scrutiny under the Official Secrets Act, between the utility and the Nuclear Installations Inspectorate (NII). The utility and its suppliers have major responsibility for technical analyses, with the NII functioning largely as a reviewer of information submitted by the applicant. The large staff, independent research budget, and capability for independent, highly sophisticated analysis characteristic of the NRC are largely absent in the NII. This is to a lesser degree also true of the other European regulatory agencies; the European systems depend, much more than those of the U.S., upon a climate of mutual trust and cooperation between the regulator and regulated and upon substantial public confidence.

Though these European regulatory systems differ in the details of their procedures, their similarities in comparison with the U.S. system of nuclear regulation are more important than their individual differences. These similarities are in the political systems under which they operate — all of which are very different from that of the United States. The most important common feature is that each of these countries has a parliamentary system of government, with the majority party or coalition in parliament responsible for choosing the national executive. The formulation of policies — which are then implemented by the bureaucracy — is much more efficient in the European systems.

In addition, in each of these countries the government mandate for defining and promoting economic, public health, and environmental goals is much clearer than in the U.S., and explicit balancing
(Article continued on page 36)

A Survey of the Utilities



What aspects of regulatory uncertainty (and its associated costs) have contributed significantly to the weakness of the U.S. nuclear power industry?

To answer this question, we surveyed all U.S. electric utility companies having lead responsibility for large nuclear projects; all but two companies responded. We asked for data and subjective responses summarizing each utility's experience with capital costs and licensing duration related to regulation of each of its nuclear projects, and for statements of its attitudes regarding the regulatory system.

The major results are:

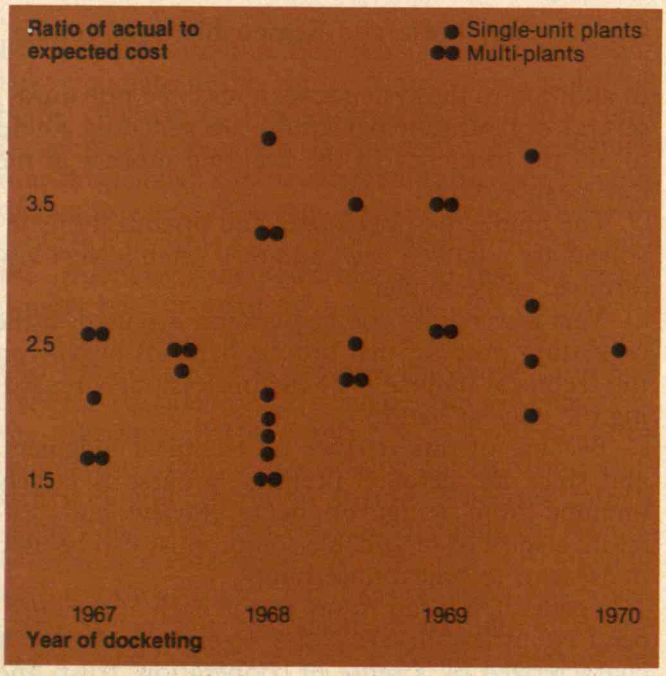
☐ Since the late 1960s, the ability of a utility to obtain a construction permit according to the anticipated schedule has been very poor. In recent years most power plants have required substantially longer time for construction-permit licensing (*see chart, page 32*) than the 22-month period NRC specifies, and utility companies have tended to underestimate the time required.

But the most significant characteristic of the licensing process is its unpredictability. The time required for licensing has varied substantially from one plant to another, and much of this uncertainty is associated with the public-hearing phase of the licensing process.

☐ Our survey also shows that the time to build a nuclear plant — that is, the period elapsed from issuance of a construction permit to the granting of an operating license — has also grown steadily during recent years as power plants have grown larger and more complex. Furthermore, a deviation from the mean construction time of approximately ten months is typical. The ratio of the longest to the shortest construction time in a given year falls typically in the range of 1.3 to 2.0. These data (*see chart, page 33*) indicate that construction schedules are significantly uncertain. Uncertainty is most costly at this stage, since delays involve additional taxes and labor costs as well as interest on previously committed capital that is not yet productive. For a typical plant completed but not yet in operation, such charges might today be as much as $320,000 per day.

☐ Cost is another important area of uncertainty. Our data indicate that no nuclear power plants planned since 1967 have been completed at costs close to the original estimates, and the uncertainty in the final budget has been large (*see chart below*).

At first glance, such cost overruns may appear to pose little risk to a utility company since, once the power station is in operation, they become part of the capital asset base upon which the company is allowed to recover revenues. But before the nuclear plant becomes part of the rate base, uncontrolled nuclear project costs can greatly reduce the ability of the utility to pay dividends to stockholders, borrow money to finance the nuclear project, and pay reasonable salaries to its executives. Often a new nuclear plant will represent a capital expense of the same magnitude as the total existing assets of a utility, and it will commonly be the largest single economic enterprise in a state's history. Thus, the uncertainties involve large financial risks for a utility company committed to a nuclear project, and this threat of potentially large cost overruns must be a strong deterrent to undertaking such projects. — *M. W. G.*



The cost of many nuclear reactors built in the U.S. during the late 1960s turned out to be significantly higher than their planners' estimates, and the trend has been toward ever-higher overruns. Though it is impossible to estimate precisely the importance of these factors, utility executives and engineers agree that uncertainties and delays in the regulatory system are the sources of a signficant portion of these overruns; and these are in turn a significant cause of the present moratorium on orders for new nuclear power plants.

Though it greatly oversimplifies the comparisons, this chart shows in barest outline the situation of nuclear power regulation in some of the Western industrialized countries whose policies are discussed in the text. Except in the U.S., legislative-type (rather than trial-like) public hearings are held where required; only in Sweden can such a public hearing result in a site veto.

	Utility pattern	Utility ownership	Regulatory pattern	Local site veto possible?	Public hearings required?	Extent of public record?	Frequency of power plant construction delays from regulation	Current nuclear moratorium?	Form of opposition to nuclear power
United States	Local	Mostly private	National, state	No	Yes	All	High	Effectively, yes	Political, guerilla warfare
France	National	Public	National	No	Usually	Rulings only	None	No	Political, violent
England	National	Public	National	No	Sometimes	Rulings only	None	No	Consciousness raising
Sweden	Local	Half public, half private	National	Yes	Usually	Most	Low	Yes	Political
West Germany	State	Mostly public	State, national	No	Usually	Rulings only	None	Yes	Political, violent

of these values is a central factor in national policy. The economic policy served by a nuclear project and the general public health and environmental protection goals governing the project are formulated in the same ministerial levels of government. In the American system, environmental and public health goals are formulated at least implicitly as state and national goals, but there is no coordination of these with any comprehensive national economic plan; indeed, there is no such plan, except with regard to the federal budget and monetary policy.

Because political activity is the major option for citizens and interest groups, opposition to nuclear power in Europe has been expressed mainly in this arena. Though there have been violent antinuclear actions, most antinuclear efforts have focused on political alignments rather than on the processes of licensing individual nuclear plants. Germany has been the major exception to this rule, with some successful opposition to specific projects through litigation.

Uniformly, both electric utility and regulatory personnel report that unjustified licensing delays are not significant factors in nuclear projects in the European countries surveyed. By contrast, such delays were commonplace in the United States even before the accident at Three Mile Island, and the uncertainties that derive from licensing delays in the U.S. are among the most serious disincentives to nuclear power development.

Cooperation, Trust, and Reasonable Compromise

In addition to the systemic features cited previously, several organizational features are generally found to aid the efficiency of the licensing process in the European systems:

☐ The numbers of personnel and organizations involved are relatively few, and they often have a low turnover of personnel.

☐ Very few rigidly codified criteria are used in the regulatory process; that process depends heavily on the technical judgment of the professionals regarding the issue at hand.

☐ Because of this reliance on technical judgment, and since the detailed licensing process is largely immune from nongovernmental review and criticism, a spirit of reasonable compromise can be used in areas of technical uncertainty.

In general, it is fair to say that in each of the European countries surveyed, the regulatory climate is characterized by a sense of cooperation, trust, and

Uncertainty in Decision Making

In addition to surveying utilities on their experiences with nuclear costs and regulation, we asked utility decision makers about their attitudes on the future of nuclear technology in the U.S. The following is a reasonably representative consensus:

□ Nuclear technology is not perfect, but it is satisfactory for utility purposes.

□ Most utility executives agree that nuclear power would be economically attractive in many sections of the U.S. under conditions of reasonable regulatory constraints reasonably applied.

□ While utility executives disagree with the need for many of the technical regulatory constraints on building and operating both nuclear and fossil plants, most agree that these constraints do not substantially inhibit their use of nuclear power. Stated differently, almost any reasonable set of design constraints is acceptable, provided that the constraints are stated clearly, with finality, and in a timely fashion.

□ The current nuclear regulatory system is perceived as capricious, irrational, and unpredictable. The use of nuclear power is substantially inhibited by the perceived high probability of significant uncontrolled costs related to these regulatory problems.

□ The possibility of citizen intervention in a licensing proceeding is not an important factor in deciding whether to pursue a nuclear project.

□ The general political opposition to nuclear power is primarily important because of its effect on the attitudes of regulatory agencies — notably the Nuclear Regulatory Commission. Such opposition includes unnecessary caution and conservatism in regulatory decision making.

□ Many utility executives suspect that the regulation of coal-fired plants will soon present problems similar to those now encountered in nuclear regulation. Indeed, many respondents said their firms are now unable to build either coal or nuclear plants for reasons associated with regulation, public acceptance, or — in some cases — financial constraints.

That the utility executives' responses may be completely in error is irrelevant; what matters is that these are the attitudes of those who are making decisions on future nuclear projects. The perception — not the reality — determines the decisions.

— *M. W. G.*

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reasonable compromise among equipment vendors, utility companies, and government regulators.

Essential Reform: The Political/Technical Split

By contrast with this European pattern, the regulatory climate in the United States seems to be far better characterized as adversarial, legalistic, cumbersome, and sometimes acrimonious. We conclude that this climate can be attributed to either or both of two aspects of the regulatory system — the procedures followed in the various regulatory tasks, and the structure of the political system that has determined those procedures.

Most attempts to "reform" the U.S. nuclear regulatory system — including most legislation proposed over the past few years — suggest improvements in the efficiency of the regulatory procedures themselves; for example, combining the separate construction and operation permit processes into a single "one-stop" process, and changing the administrative structure of the NRC. But it is our view that such reform attempts that focus on improved procedures or greater management accountability are likely to be ineffective. This is because most of the fundamental problems of nuclear power regulation arise from the nature of the regulatory system itself and not from its procedures.

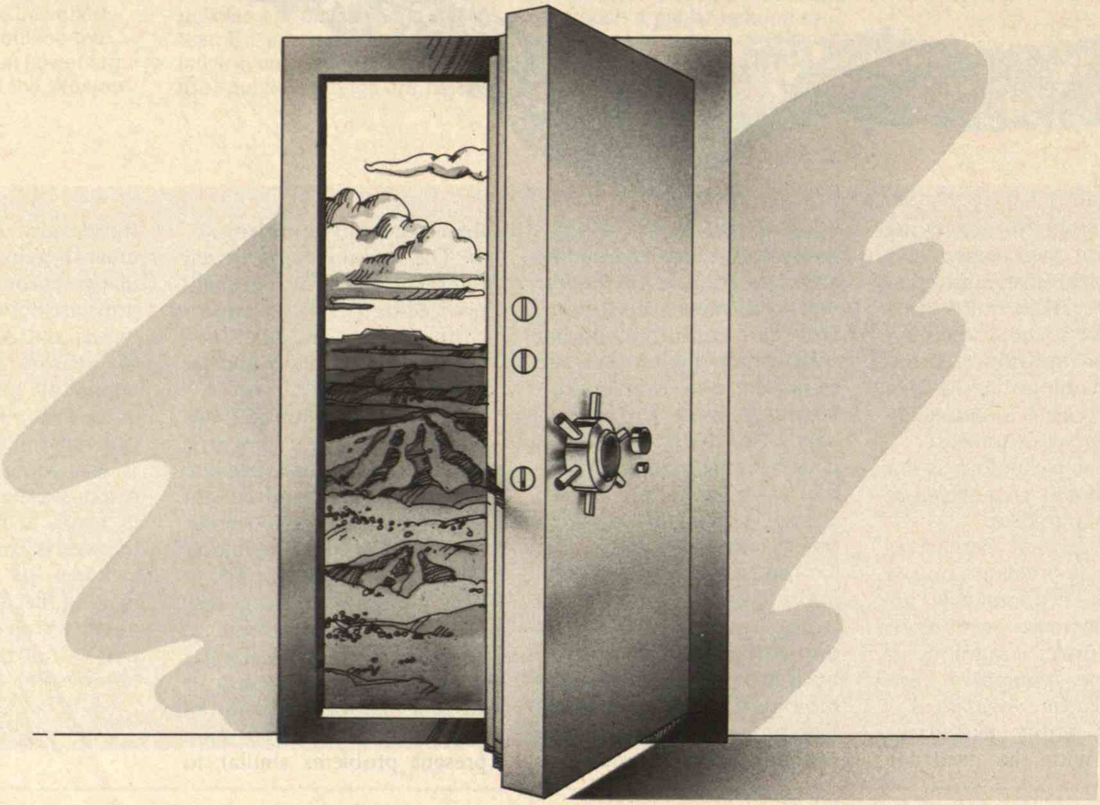
The essential reform needed for the U.S. nuclear regulatory system is the separation of political and technical issues. The two related goals should be:

□ To treat issues of public health and safety and of economic welfare as related generic questions; and

□ To provide new avenues for resolving the political issues that affect nuclear power.

We should begin by resolving the generic issues, largely political, of defining socially acceptable levels of environmental and health effects. Then we can deal with specific issues of how successfully a particular technology or project design meets the specified criteria. The definition of standards inescapably requires a balancing of economic and public health protection goals, and this fact should be explicitly recognized in any standard formulated. Currently, the criteria of public safety are very uneven regarding the levels of risk tolerated from the various energy technologies and the areas of life in which risk is incurred. For example, we insist that most nuclear hazards to the environment and public health are reduced to very low levels, while some nonnuclear effects are tolerated at much greater hazard levels. A rational system — providing bal-

How locking federal lands away from oil and natural gas exploration will lower America's standard of living.



For some time now, the United States has been increasing its oil imports—at higher costs year after year. When more and more dollars leave the country to pay for this oil, the effect is a lessening in the value of the dollar... and a nibbling away at every American's standard of living.

To help cut its dependency on foreign oil, America must produce more oil and natural gas here at home. Our country has rich, untapped reserves; the problem is that much of them are under federal lands. About a third of our country is controlled by the federal government. Most of this land is currently off limits to energy exploration and development. And proposed legislation would shut these lands off permanently.

Energy lands should be developed.
Just one example: in the Rockies of Idaho, Montana, Utah and Wyoming, a mineral-rich geologic area that's part of the "Overthrust Belt" contains an estimated 8 billion barrels of oil and 100 trillion cubic feet of natural gas. But nearly half of this land may be put off limits.

Some government land management people feel that they have to draw a permanent line on land use: a line protecting every facet of the environment in its natural state from oil and natural gas development. At Amoco, we believe that energy can be produced on these lands while maintaining their natural integrity.

The environment can live with oil and gas development.
Now don't get us wrong. We are not for the wholesale exploitation of America's natural wilderness. But we would like to be able to explore public lands to find those having the potential for holding oil and natural gas deposits. Further, we'd like to be permitted to drill on those lands where large quantities of oil and natural gas are most likely to be found.

Amoco believes that America can't afford to cut itself off from any opportunity to increase its energy reserves. Because producing secure American petroleum supplies is the best way to lessen the influence that foreign oil producers have on every American's standard of living.

America runs better on American oil.

AMOCO

anced protection — would require all energy technologies to meet the same minimum levels of health effects and to fall within an envelope of allowed environmental impacts.

Public Participation: The Intervenors

If political issues are to be removed from nuclear project licensing, alternative avenues must be established for their resolution. This implies a need for new institutions or for the transfer of these political burdens to existing institutions that can more satisfactorily deal with the technology-risk dilemma.

The role of intervenors in licensing is a unique feature of the U.S. nuclear regulatory system, flowing from the American tradition of making the functions of the bureaucracy easily accountable to the citizens. Intervenors are generally credited with raising important reactor safety issues that the NRC staff had previously ignored. But the experience has actually been that, while intervenors and "public interest" groups have been important in publicizing neglected safety issues, they have not had a basic role in initially identifying such hazards. We do not mean to demean the importance of this role. Indeed, intervenors have caused many improvements through the threat of criticism and exposure of inadequacy in regulatory agencies.

But another result of the public attention focused on intervenors has been less beneficial. In particular, regulatory actions and criteria have not been determined (even in principle) by an objective process of marginal risk evaluation; instead, such reviews have strongly reflected the concerns of antinuclear pressure groups. Enhancing the influence of intervenors will exacerbate this tendency.

Though the Three Mile Island accident will surely result in reorganizing the priorities assigned to safety issues and the management at the NRC, nothing suggests that fundamental changes will occur in the political system for identifying priorities or resolving conflicts where public safety is concerned. Consequently, the nuclear regulatory situation is likely to become more rather than less inconsistent, arbitrary, and frustrating.

The Price of Regulatory Uncertainty

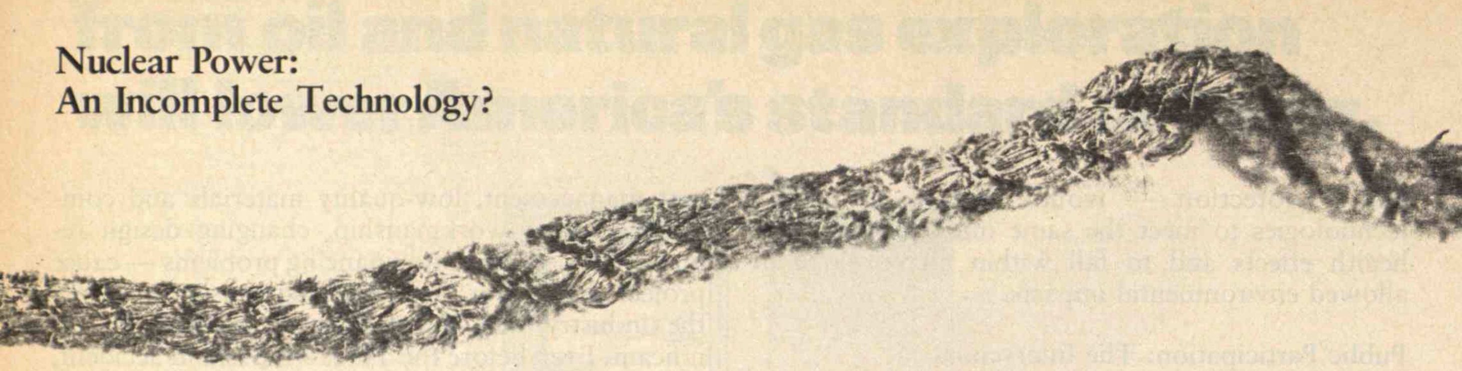
It is impossible to state with any precision what fraction of the delays recently experienced in U.S. nuclear projects (*see box on page 35*) are due to the regulatory system. Many other factors — incompetent management, low-quality materials and components, poor workmanship, changing design requirements, strikes, and financing problems — cause project delays. But there is strong consensus within the industry that the regulatory problem is significant. Even before the Three Mile Island accident, the unique features of U.S. nuclear power regulation were imposing significant costs upon society; several utility companies, despite their confidence that nuclear technology is safe, reliable, and — in most parts of the country — economically competitive, had decided to defer future nuclear projects until regulatory uncertainties were substantially reduced. This has become virtually the universal attitude of the utility industry since that accident, largely because of the resulting political and regulatory chaos.

In summary, the U.S. regulatory system is inimical to nuclear power expansion through creation of a climate of great uncertainty regarding the schedule, design, and cost of a nuclear project; this climate is unique to nuclear projects, and could preferentially discourage utility companies from investing in nuclear technology because the competing technologies are not subject to the same uncertainty.

In the future, this situation may change if environmental controls and economic factors lead to de facto moratoria on the use of some alternative technologies; there is a strong expectation of this in the electric power industry. If this happens, the anticipated power shortages and attendant economic pains are likely to provide a stimulus for rationalizing the public health and safety system. While such restructuring would be welcome to many people, it would likely be accompanied by some less-welcome side-effects, such as some form of socialization of the electric utility industry and an increase in the size of the basic organizational unit to a regional scale. The experiences of the European countries we studied suggest that these outcomes might be beneficial for everyone, but they would be profound disappointments for the current leaders of the American utility industry and for many who have invested in it.

Michael W. Golay is associate professor of nuclear engineering at M.I.T. He came to the Institute in 1971 following undergraduate study in mechanical engineering at the University of Florida (B.M.E. 1964) and graduate work in nuclear engineering at Cornell (Ph.D. 1969); since then he has worked in power plant engineering, especially heat transfer, fluid flow, and environmental problems. He held the Institute's Arthur D. Little Professorship of Environmental Sciences and Engineering for two years beginning in 1971. The work reported in this article was part of the M.I.T. Energy Laboratory Light Water Reactor Project sponsored by the U.S. Department of Energy.

Nuclear Power: An Incomplete Technology?



by Michio Kaku

In the 23 years since the first nuclear facility at Shippingport, Pa. sent electricity into the grid, commercial nuclear power has logged over 450 reactor-years of operation without a single radiation fatality. That's quite a safety record, one that no other major industry can match.

The safety mechanisms built into a reactor are truly impressive. Several layers of safety systems prevent an uncontrolled release of fission products into the atmosphere. First, tough zirconium cladding seals the uranium dioxide pellets — up to 100 tons of them — into the fuel rods. The fuel rods are then encased in a steel reactor vessel with walls eight inches thick. A labyrinth of pipes to carry cooling water provides a sophisticated fail-safe program: the emergency core cooling system. Finally, the reactor is housed in a reinforced concrete dome four feet thick with a steel liner. And throughout the system are redundancies to reduce the chances of failure.

For all its successes and despite all the precautions, however, stubborn obstacles still cast a shadow over the fate of nuclear power. Perhaps, as some suggest, many of these nagging doubts come from Cassandras who would have us roll back the wheels of progress. On the other hand, perhaps some of these problems warrant more study.

The hallmark of any mature industry is that it eventually shakes off its early record of glitches and bugs. But behind the industry's perfect batting average of no meltdowns there is a persistent background of literally thousands of small accidents every year. According to the Nuclear Regulatory Commission (NRC), there were 3,002 small safety-related incidents involving nuclear reactors in 1977 alone (1,222 in boiling-water reactors and 1,780 in pressurized-water reactors), or 8 small incidents per day. Most of these "reportable occurrences," as the industry calls them, are no more dangerous than a gummed-up control rod or a hairline turbine crack — hardly the basis for extraordinary concern. But a few incidents have triggered unpredictable, cascading sequences of errors. These have led to "close calls" such as the Brown's Ferry fire in 1975 and the accident at Three Mile Island (TMI) — incidents that apparently injured no one but that came uncomfortably close to exceeding prudent margins of safety.

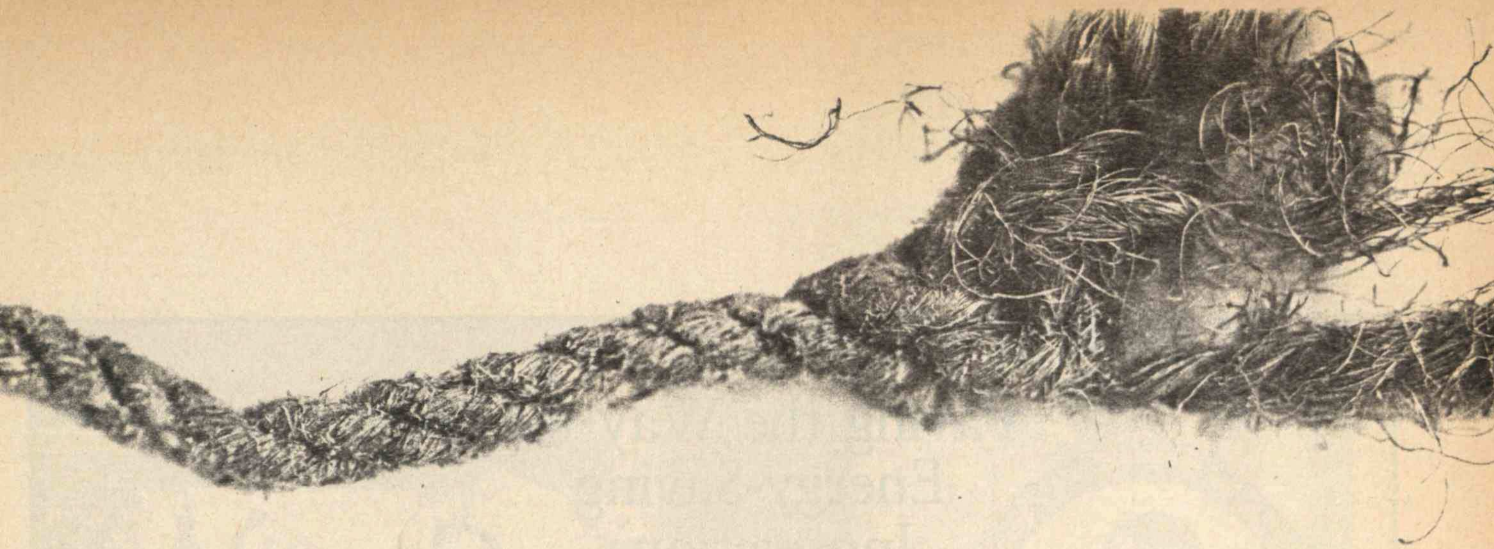
The nuclear industry and many of its observers claim that the accident at Three Mile Island shows just how rugged nuclear power plants really are. There is some truth to this. Almost every abuse was hurled at the reactor core, but it didn't melt down. It may have sustained 90 percent damage to the core, released over 10 million curies of xenon-133 over Harrisburg, and dumped almost a million gallons of cooling water throughout the reactor — but it did not melt down. It did not melt down even though it was exposed (for durations up to three hours) at two hours, five hours, and again at nine hours after the original turbine trip. (Previously, we had accepted the figure that it takes little more than an hour to melt down the core and another few hours to melt through the waterless reactor vessel.)

But if this shows that the TMI core was unusually rugged, it shows the flip side as well: that there was a certain amount of luck involved in the accident. In other words, if the core was uncovered by accident, then we must also admit that the core did not melt down largely by accident. According to the Electric Power Research Institute, steam and radiative cooling in the exposed nine feet of the core helped to keep temperatures down — a new, unexplored, and fortuitous scenario that occurred without the knowledge of the operators. And the NRC's Rogovin Report concluded that we came within 30 to 60 minutes of a meltdown (although a breach of the containment was deemed unlikely).

The "Kemeny Commission" (the President's Commission on the Accident at Three Mile Island) criticized the NRC and Metropolitan Edison, operator of TMI, for compromising safety procedures, for deficiencies in maintenance and emergency preparedness, and for inadequate evacuation plans. It also called for upgrading the education and training of nuclear operators. Perhaps an elite corps of nuclear operators, with salaries and training comparable with those of airline pilots, will help to reduce the level of nuclear accidents. But the fact is that TMI showed how it is possible to trigger an avalanche of multiple failures that could frustrate the best efforts of the industry and the NRC.

The Kemeny Commission also submitted to President Carter a "Technical Staff Analysis Report on Alternative Event Sequences" that contained engineering studies on hypothesized sequences of "worst-possible events" at TMI. What if the high-pressure injectors (HPI) had been turned off completely? What if the pilot-operated relief valve had stayed stuck? The report concedes that the core would have melted down completely had the HPI been totally turned off by the operators, but reassuringly adds that a meltdown that breached the containment would have been highly unlikely.

The technical staff report, however, is perhaps more revealing about what we don't know than what we do know about nuclear meltdowns. Model calculations, admittedly, are just that: models. In all fairness, no one knows precisely what would happen, for example, if an emergency core cooling system (ECCS) should completely fail and 100 tons of uranium dioxide were to melt and slump down



into the lower plenum of a reactor vessel.

If the core is completely uncovered, there are at least four ways the last line of defense, the containment building, could be breached: by an explosion of hydrogen gas, an explosion of steam, the melting of radioactive material through the base of the building (the China syndrome), or simply the escape of overheated materials whose pressure exceeded the capacity of the containment to resist. After three decades, our best understanding of this obscure but crucial area is as follows:

□ The TMI dome was officially rated to withstand 60 pounds per square inch (psi) of pressure. The dome would probably start to crack at pressures greater than 90 psi, although it is not clear if a hydrogen gas explosion can reach these pressures. If one assumes that all 2,200 pounds of hydrogen gas that can be generated by the zirconium metal-water reaction detonate at once, then one can expect a 166 psi explosion. But because the impulse time of the explosion is below the dome's period of natural oscillation, such a detonation may not be large enough to shatter the dome. The technical staff report concludes vaguely: "If all the hydrogen detonated, the pressure loads imposed are calculated to be somewhat less than the strength of the building."

□ *WASH-1400* (The *Reactor Safety Study*, or "Rasmussen report") concludes that if more than 20 percent of the core melts, then the containment may fail in the resulting steam explosion. In one scenario, the molten core slumps onto the grid plate in the vessel and partly refreezes. The molten core continues to accumulate over the grid plate until it finally melts through. When the molten uranium and molten grid plate slump simultaneously into the water in the vessel's lower plenum, a steam explosion will blast a pistonlike slug of water against the head of the vessel. If the kinetic energy of this water slug is sufficiently great, it could knock out the top of the reactor and vessel, and then the control rod shield block, until "the combined projectile penetrates the dome of the containment building, 95 feet above the shield block."

While conceding there would be more than enough kinetic energy to send the projectile or shrapnel through the roof of the containment building, the technical staff report stresses that such a steam explosion is unlikely.

Unless it falls in one coherent piece into the water, with maximum surface contact and hence heat transfer to the water, the core may not convert enough thermal energy to kinetic energy. The reactor dome can withstand an explosion of up to 900 pounds of TNT. A steam explosion, by contrast, may be able to generate a maximum of 10 *tons* of TNT. The key, of course, is to know what fraction of the 10 tons of TNT explosive force may be generated in a realistic meltdown sequence. No one knows the answer. The American Physical Society (APS) report on reactors adds, "Our predictive ability of steam explosions is very limited. About all that can be stated is that localized explosions yielding local pressures on the order of 3,000 psi (200 atm) might occur."

□ There is the chance that a failed and molten core will simply melt its way through the concrete basemat in a "China syndrome." *WASH-1400* estimates the process would take from 13 to 28 hours, after which the core would melt through 10 to 50 feet of soil. But this estimate is not without question. The technical staff report draws on several conflicting studies done after *WASH-1400* to state that (1) the core might take 13.5 days to penetrate a 20-foot-thick basemat; or (2) or it might not even penetrate a 13-foot basemat. The situation is unclear.

□ Even if there is no explosion or China syndrome, there is the great likelihood that simple overpressurization could crack the containment structure. *WASH-1400*'s extensive computer programs show that the combined pressures caused by steam, hydrogen, and carbon dioxide are enough to breach the dome in roughly 5 to 15 hours, depending on how the ECCS is disabled. And the APS report tersely states that the $.45 \times 10^9$ Btu of heat it takes to reach the 100 psi pressure necessary to rupture the containment could be exceeded under meltdown conditions.

This discussion, of course, is hypothetical. But because a full-scale test of the ECCS has never been done and a realistic meltdown experiment has never been conducted, there are gaps in our technical understanding. Previously, such gaps were not worrisome because the probability of a meltdown was considered much too small. But after Three Mile Island, our cherished notions of probability have to be revised.

Although this probability still remains low, no one can question that in the event of a meltdown, the uncontrolled release of a large percentage of the fission product inventory of a reactor could cause fatalities in the tens of thousands. What *is* questioned is whether the nuclear power industry has matured to the point that it can adequately manage nuclear accidents. Can the utilities handle this unforgiving, seemingly unfinished technology?

In the past, critics had to show why nuclear power was dangerous. The burden of proof has shifted to the nuclear industry. It must now show, to the reasonable satisfaction of the American people, that nuclear power is safe.

Michio Kaku is associate professor of nuclear physics at the City College of New York. He received his Ph.D. from the University of California at Berkeley in theoretical physics, and has taught at Princeton. □

Paving the Way for Energy-Saving Innovations

by
David G. Jansson
and George C. Newton, Jr.

For inventors, raising capital has always been an especially difficult task. But new assistance from the federal government may help them develop energy-saving innovations.

Imagine you're an inventor with an idea for a device or process that could save a great deal of energy while doing its task. You've figured out the capital required to produce a prototype product and calculated the return on investment that could be expected by users of your energy-saving innovation. What then? Your urgent problem is to find the venture capital to make it all happen.

Even if they have sound business plans, inventors often have trouble winning over venture capital organizations for financing. Venture capital firms have stringent criteria for investment, which include a "track record" for a product or products and a business plan to reasonably assure recovery of the capital with a substantial profit in a relatively short period. A return-on-investment factor of three to ten over a period of three to seven years is not an uncommon requirement. As a result, first-time inventors with an unproven technology typically have to obtain financing through friends and relatives or from wealthy individuals willing to take great risks.

Most inventors have difficulty finding capital after fashioning a crude prototype and before their inventions become attractive for investment by venture capital firms. The recent Energy-Related Inventions Program of the Department of Energy (DOE) is filling this gap to some extent with public funds.

The Legal Basis of Federal Grants to Inventors

The Federal Non-Nuclear Energy Research and Development Act of 1974 (Public Law 93-577) provides for "incentives, including financial awards, to individual inventors" to encourage participation in a national effort to develop more efficient means of producing and using energy. In response to PL 93-577, DOE has instituted the Office of Energy-Related Inventions (OERI) in the National Bureau of Standards (NBS). OERI evaluates disclosures submitted by inventors and recommends the best to the Office of Inventions and Small-Scale Technology in DOE for financial or other assistance. The law also addresses the need to assess the environmental and social consequences of any DOE-supported effort and to ascertain the likelihood of an inventor's obtaining private investment once DOE support has been exhausted.

The effort to assist individual inventors of energy-related devices differs significantly from more conventional government-sponsored research and development programs that strive to increase scientific knowledge and advance technology. This program more pragmatically focuses on stimulating the innovative process to assure that high-quality, energy-saving products and processes reach the

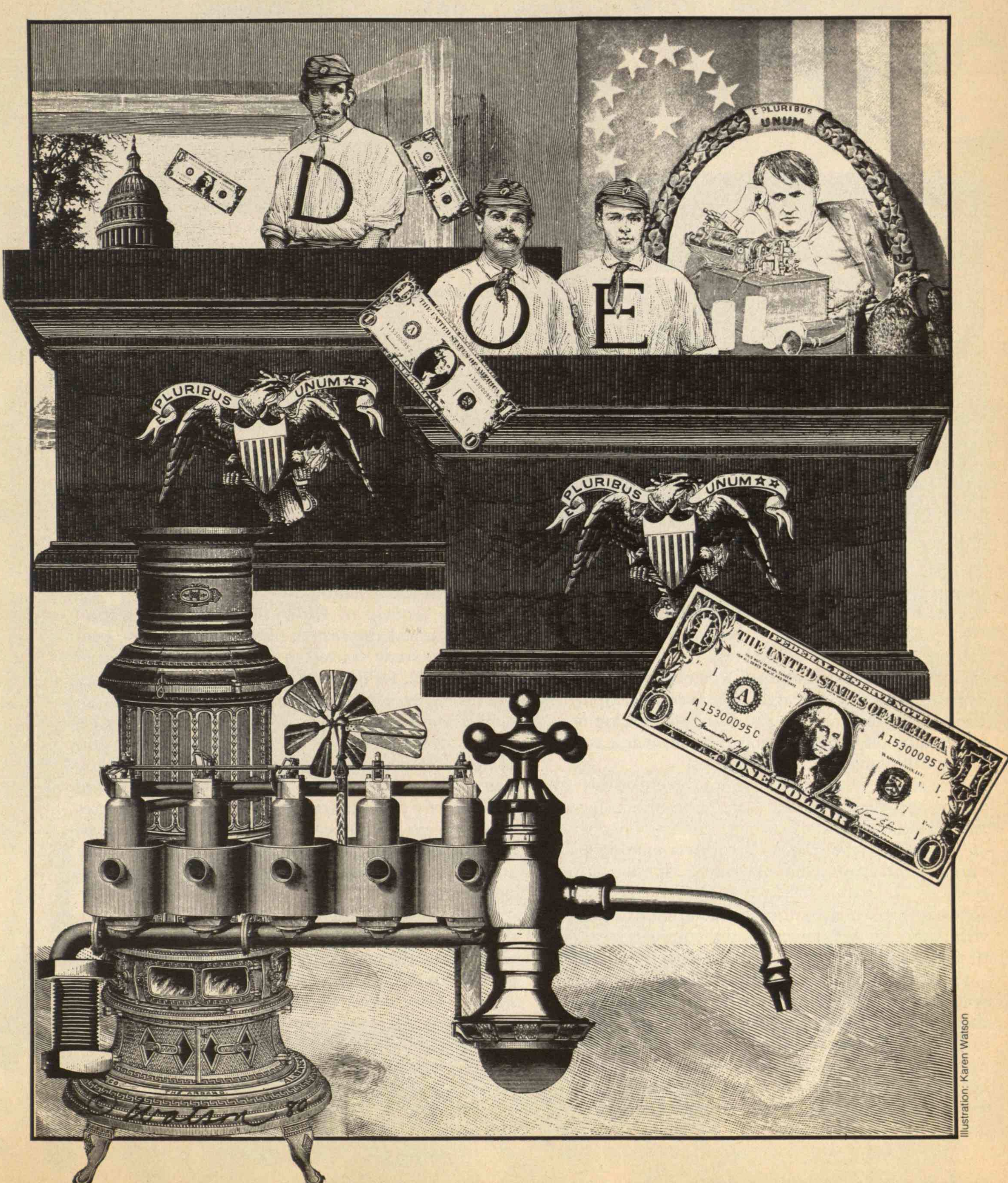


Illustration: Karen Watson

A market risk analysis of 41 inventions accepted for DOE support. (The number of inventions accepted for support has since risen to 128.) The 41 inventions are classified by major market area and are assessed for the degree of difficulty likely to be experienced when introduced into their respective markets. Note the reasonable balance in the allocation of awards with respect to the several market areas.

Major market area	Difficulty in Penetrating market	Number of positive award decisions
Industrial	low	15
Commercial	low	2
Agriculture	medium	2
Buildings	medium	11
Automotive	high	7
Appliances	high	1
Other	high	3
Total positive decisions as of December 31, 1978		41

marketplace and are assimilated into the economy. However, it is broad enough to embrace promising projects in basic research, product development, product demonstration, and business development. Minimally, the program aims to achieve at least one of the following specific objectives:

□ To enable inventors to compete effectively for public or private contract support to obtain further development assistance.

□ To enable inventors to form new enterprises to pursue production and marketing of their inventions.

□ To help place inventors in a position to negotiate with existing companies for the commercialization of their inventions.

One of the unusual features of the DOE program is its encouragement to award recipients to transfer their new technology into the marketplace. In addition to giving financial support, DOE waives patent rights back to the inventor subject to a royalty-free license to the government, and the federal government is given the privilege of stepping in if the inventor fails to make progress on patenting and commercialization. Thus, the intent of Public Law 93-577 is fulfilled while the public is protected against an inventor's failure to transfer technology to the marketplace.

The Batting Average

As of December 31, 1979, the National Bureau of Standards had received 13,215 disclosures from individual inventors or their licensees; such disclosures are now arriving at a rate of about 70 per week. So far, the NBS has recommended 128 for the award of grants or contracts. Of these, support or assistance has been given to 65 and 6 others are in negotiation; 11 have been rejected by DOE and 46 are still under review. Of the 65 inventions that have received support or assistance, work has been completed on 17. The average award is approximately $65,000, excluding the value of government services available to some of the inventors.

At the request of DOE, the M.I.T. Innovation Center studied the results obtained under the program. The study started in fall, 1978 and ended in spring, 1979. Of necessity we had to focus on those inventions on which grant activity was either completed or quite far along. We selected from these a representative sample of five for detailed study. This sample includes innovations with both high and low potential for commercial success. We have found conclusively that the stream of invention disclosures does contain a significant number of worthy ideas, and that the societal return on those that eventually come into public use appears likely to repay the nation manyfold.

One criterion is energy conservation. In addition, there is an economic analysis of each invention that emphasizes the energy-related parameters of return on investment, defined as the net annual income or savings, after taxes, divided by the average capital investment. An investment return on the order of 20 percent typically is considered relatively good for low-risk investments; a return of less than 20 percent is likely to be unattractive unless other reasons override. Such reasons might include a special need for energy conservation because of limited energy

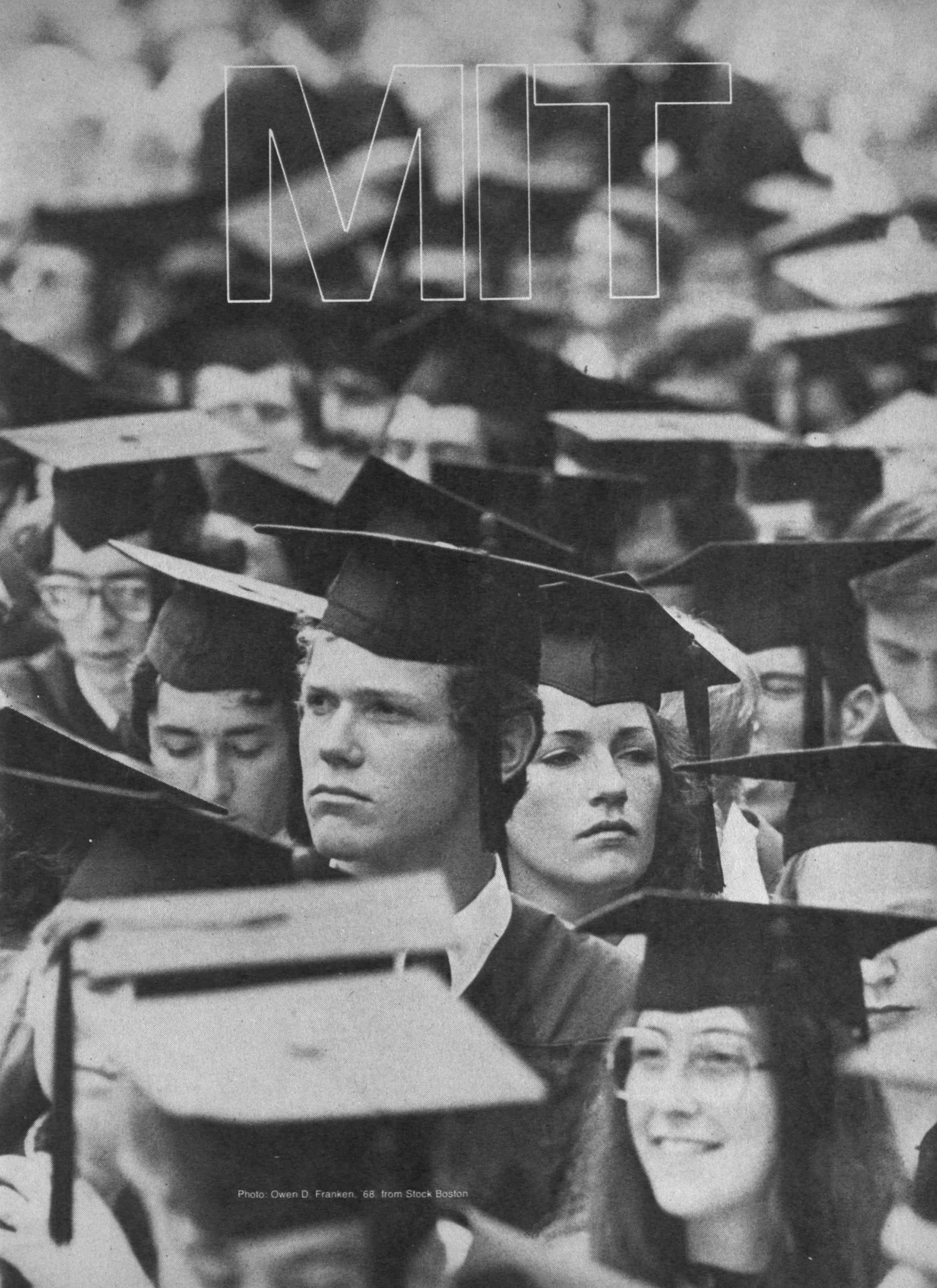


Photo: Owen D. Franken, '68, from Stock Boston

As President Wiesner Retires, an Outpouring of Praise for Quiet, Wise Leadership

He had almost mailed a letter turning down the offer to go to the Radiation Laboratory. Only his wife Laya's encouragement had turned the tide — after all, she argued, Rad Lab wanted him to work in electromagnetic field theory, which was far nearer his University of Michigan doctoral thesis than recording folk songs in Appalachia for the Library of Congress.

They liked him at Rad Lab, and as the war ended, on September 19, 1945, James R. Killian, Jr., '26, then president of M.I.T., wrote what he calculated was a persuasive letter offering an assistant professorship for three years. The annual salary was $5,000; "We believe that opportunities here over the coming years in your field of interest will provide you with ample scope for your work," Dr. Killian wrote. "We look forward with much pleasure to having you join us at the Institute."

Jerome B. Wiesner accepted that offer, and in the 35 years since then none of the parties to it — Dr. Killian, Dr. Wiesner, Laya Wiesner, and the Institute as a whole — has had any reason for regret. "An absolutely unique, wonderful existence . . . most rewarding years . . . if we were given a chance to choose our next life, we'd come right back to M.I.T.," Dr. Wiesner told the faculty on May 20 following a standing ovation at the last faculty meeting over which he would preside.

As chairman of the last faculty meeting of the year, Professor Shiela Widnall, '60, had planned to ask for a standing vote of the faculty on its resolution of tribute to President Jerome B. Wiesner. But the matter was taken out of her hands by the ovation which came even before a motion was on the floor. When his chance came, President Wiesner was both pleased and diffident: "So many people in this room I've worked with so long . . . people have given me much more credit than I deserve for what has happened at the Institute."

"Indelible Footprints" from Big Shoes

It was the first in a series of events through which the community paid tribute to Dr. Wiesner for his leadership of M.I.T.— as director of the Research Laboratory of Electronics (1952-61), acting head of the Department of Electrical Engineering (1959-60), dean of the School of Science (1964-66), provost (1966-71), and president (1971-80). The events of May 20 and 21 confirmed what Dr. Wiesner's career had already made obvious: this is by no means an ordinary electrical-engineer-turned-administrator. Everyone at M.I.T.— but especially the faculty — poured forth tributes at a faculty meeting, community reception, day-long symposium, and finally a gala banquet.

One of the warmest (*next page*) was from Paul E. Gray, '54, who will succeed Dr. Wiesner on July 1. "You have left indelible footprints on the Institute," he said — "footprints which . . . point a way toward the future. The shoes that left those marks are large ones . . ."

A formal faculty resolution called attention to the special achievements of the nine years of Dr. Wiesner's presidency: expansion and invigoration of the arts, major new efforts in health sciences, technology, and management and in cancer research, establishment of a Division for Study and Research in Education, and a new program in science, technology and society. "At the end of Jerry's presidency, M.I.T.'s activities and horizons are broader than ever before," said the faculty.

"In the 38 years that Jerry has been at M.I.T. we have watched him grow from a young, talented engineer . . . into a man of great breadth of knowledge, personal warmth, and a special gift for enhancing the intellectual efforts of others."

Charles Markham, '81, president of the Undergraduate Association, praised Dr. Wiesner's "contributions to the quality of student life." Sharon Lee, vice president of the Graduate Student Council, brought a similar message from her constituency: graduate students "are no longer clients but partners in their education" because of qualities brought to the Institute by Dr. Wiesner.

Professor Heather Lechtman, who teaches anthropology, spoke for her colleagues in the humanities and the arts, bringing the thanks "of those of us who are not really in the mainstream for his effort — intellectually and from the heart — to make us in the mainstream." Others — women and minorities — who were not in the mainstream also gained from Dr. Wiesner's commitment to diversity at M.I.T., said Professor Vera Kistiakowsky.

Howard Johnson, chairman of the Corporation, spoke of Dr. Wiesner's contributions to the Leadership Campaign: he has "so often submerged things he wanted to do because of his commitment to the corporate purpose. In so doing he has furthered the progress of education and research and enhanced the opportunities of every student and every member of this faculty. We are forever in his debt," Mr. Johnson said.

Turning Problems into Opportunities

But it is Dr. Wiesner's intellectual power coupled with abiding optimism that clearly set him apart for the majority of his colleagues. At the farewell dinner, Professor Phyllis Wallace of the Sloan School reminded the faculty that Dr. Wiesner was *their* choice for the presidency in 1971, and the years since then, she said, had only cemented "the crazy kind of love that the faculty feel for this man."

After one year of working with him as chairman of the faculty, Professor Robert I. Hulsizer, Jr., Ph.D.'48, is stunned by Dr. Wiesner's "penetrating vision . . . time after time he has brought light and wisdom to situations that seemed to have nothing but

continued on page A5

The Chancellor's Tribute to His Mentor: "Wise, Human . . . Smarter than Anyone"

When Paul E. Gray '54, chancellor, becomes president of M.I.T. on July 1, his task will be to fill large shoes that have left "indelible footprints on the Institute." Here is the text of Dr. Gray's remarks at the faculty banquet in President Jerome B. Wiesner's honor on May 21:

My association with Jerry Wiesner has been the central moving force in my life for the past decade. But the task of talking about working with this man — like the man himself — is formidable indeed. Let me see if I can capture for you some of that spirit.

Imagine, if you will, a meeting of the Academic Council of the Institute. We have been engaged for some time in a heated discussion of a problem that appears to be intractable; alternatives have become sharply defined, and the common ground is harder and harder to discern as the argument continues.

Quietly, without announcement or warning, Jerry appears in the room through a side door, preceded only by a cloud of pipe smoke. The door, slightly ajar, remains undisturbed by the new arrival. He is just suddenly there. Soon his vest is unbuttoned, his shirtsleeves rolled, and he is munching on an apple. Three minutes. And then, as suddenly as he appeared, he breaks into the discussion with a question which has the effect of turning the argument upside down. A new perspective emerges. Convergence on a better alternative begins.

Archibald MacLeish's line for this phenomenon is, "Not what you think, but what you haven't thought of."

A few more minutes pass and this brooding presence becomes bored with the proceedings, winks to those across the table, whispers devilish puns to those nearby, shuffles restlessly, and then, suddenly, walks out through the same door, in search of a cup of coffee. All that remains is an apple core, the aroma of the pipe, and solid agreement on the way to deal with the seemingly intractable problem.

Who is this man? How does he do it?

Jerry is a genius, many have said. He is smarter than anyone else at any given moment. He is wise; he is human. But tonight, in the family of Tech men and women assembled here, it is my assignment — as we celebrate Jerry and Laya — to examine, in the language of electrical engineers, the componentry of Jerry's genius. My amateur analysis suggests four unique qualities in his brand of statesmanship:

☐ *First*, his obvious delight in absorbing the broad sweep of the Institute's intellectual activities and his astonishing level of understanding of so much of what goes on here. In countless meetings of visiting committees, I have been overwhelmed by Jerry's evident understanding of not only the subject at hand but the intellectual context in which it is embedded. Like the Turks, who are said to be surprised each year by the arrival of spring, this experience bowls me over every time. As an observer, I am impressed; as his chancellor, I am enthralled; as his successor, I am quite intimidated.

☐ *Second*, Jerry's willingness to explore *all* possibilities in dealing with problems, even those possibilities which are evidently impractical or irrelevant. How frequently these easy *a priori* judgements turn out to be wrong. This proclivity is both exhilarating and bewildering to those who work closely with Jerry, for that mind which so readily draws in novel ideas often hands them back transformed and enriched. In short, this characteristic contributes greatly to an administrative environment which fosters creativity and discounts the *status quo*. It can be a very heady atmosphere!

☐ *Third*, Jerry's persistant unwillingness to regard any discussion as closed, any decision as irrevocable. This quality has certain unsettling effects on an organization, of course. I have said that it sometimes resembles playing badminton with a marshmallow; one is never sure whether it will stick or bounce. Nevertheless, this willingness to reconsider in the light of fresh data or increased understanding has been, for M.I.T., a source of strength. While we've made our share of mistakes in the past nine years, few have been ratified by holding to prior positions in the face of changed circumstances, and Jerry deserves most of the credit for this wholesome attitude of managerial skepticism.

☐ *Finally*, Jerry's singleminded insistence on quality, on close attention to the goal of excellence, in all that we do. He has insisted not just that M.I.T. be the best of the science-based academic institutions but that it strive to be in the front rank of world-class universities. He has, by building on the foundations laid by his predecessors and by striking out in response to his own instincts, largely realized those objectives. M.I.T. has become, in his phrase, an international symbol of science. It is clear that the Institute has moved upward in recent years, thanks largely to Jerry's leadership and his vision of excellence.

There is much more that could be said, including a description of Jerry's gentle affinity for students. But to summarize in two sentences I will say, Jerry, only that you have left indelible footprints on the Institute —footprints which both define where we are in 1980 and point a way toward the future. The shoes that left those marks are large ones, as I know better, perhaps, than anyone else present in this company of friends and admirers.

When Jerome B. Wiesner retires as president, Laya W. Wiesner perforce retires as M.I.T.'s first lady; and while the faculty was paying its tributes to her husband, Laya was learning of the community's affection from her own constituencies. Margaret H. Compton, whose late husband was ninth president of M.I.T., was the Women's League spokesman for Laya's devotion to the Institute and her "concern for the warmth and comfort and happiness of this community." To Mrs. Compton (left in the left picture) came the privilege of telling Laya of the Laya Wiesner Award, to be given every year to a deserving woman student, a commemoration of Laya's efforts to provide "a congenial and stimulating environment for women students at M.I.T." A later gathering of women students in McCormick Hall (right) confirmed the affection they and Laya share.

turmoil and trouble." Dr. Gray recalls how his mentor can ask the crucial question "which has the effect of turning the argument upside down. A new perspective emerges. Convergence on a better alternative begins . . . solid agreement on the way to deal with the seemingly intractable problem."

Dr. Wiesner's real contribution to the Washington scene was his ability to ask questions, his voice of "reason . . . in an age of threatening unreason," said Anthony Lewis of the *New York Times*, who was writing from Washington during many of the years that Dr. Wiesner served in the White House. "Devotion to principle and to the facts came first," said Mr. Lewis of Dr. Wiesner, ". . . a humanist who thinks science is fundamentally a humanistic activity."

Coupled to this intellectual power is an abiding optimism about human affairs and faith in the power of knowledge to improve them. Though our country is full of "public mourners and dour analysts of the future, I do not count myself among them," Dr. Wiesner told Nina McCain of the *Boston Globe* this spring. "I don't think science and technology have outrun man's ability to control them," Dr. Wiesner told Ms. McCain.

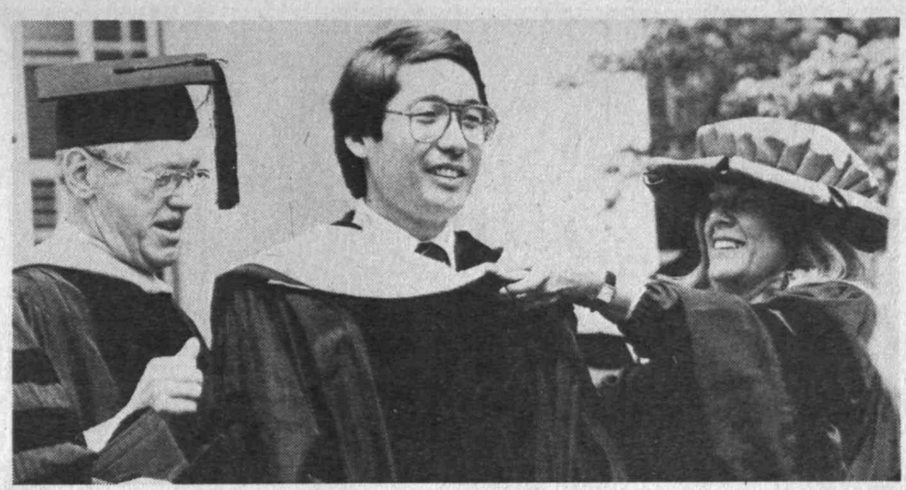
Professor Morris Halle cited this same attitude for his faculty colleagues: "Fundamental to Dr. Wiesner's approach is his confident belief that all problems are amenable to solution . . . that they are all opportunities for learning, change, and improvement."

Reaching for Imagination

When his turn finally came, Dr. Wiesner — true to the image which his colleagues had painted — offered a few sentences of his own about problems and opportunities: "When I was a young assistant professor, M.I.T. was a place where you could do anything you pleased provided it made a little sense." Dr. Wiesner thinks this need "to maintain an open, free, challenging environment" must be at the top of his successor's agenda. He has tried hard, Dr. Wiesner said, to make M.I.T. a "refuge for people who need to think and speak out. Supporting such people," he said, "is the most important thing the Institute can do in the decade ahead.

"Many years ago, when we began the M.I.T. Council for the Arts, the poet Stanley Kunitz said, 'There are many disciplines but only one imagination.' What this means to me is that we have a major responsibility to see that imagination has the broadest possible reach." — *J.M.*

To President and Mrs. Wiesner from a grateful faculty: "Two Owls," a stone carving by the noted Eskimo artist Sheokju. Professor Shiela Widnall (right), chairman of the faculty, quipped, "We thought for a while we would give him Building 20 . . ." and President Wiesner would have liked that, he said. He's looking for an office, and Building 20 is "the place in which I'd feel most comfortable." (Photos, pages A2-A5: Calvin Campbell)



Graduation: Pomp and Elegance, Elation and Wistful Goodbyes

In its new Killian Court setting, the drama of commencement is far from understated. A minor marvel of planning yields every graduate his or her own degree when the name is called; graduate students receive the hood which is appropriate to their new rank in the world's intellectual heirarchy; and the president of the Alumni Association (above, Claude W. Brenner, '47) has the central role that symbolizes the respect in which M.I.T. holds those who hold its credentials. (Photos: John W. Lepingwell, '80)

Hiking boots, sandals, sneakers, and dress shoes stick out beneath black robes enveloping 1,433 seniors and graduate students. Corduroys, shorts, and fancy dresses peek through the luxurious black folds.

Graduation day shatters the normal monochrome of M.I.T. Flowers and spring finery surround the whole range of family, from babies perched on shoulders and nestled in strollers to grandparents; pomp and elegance prevail.

More than 6,000 relatives and friends share each other's pride, sitting or standing under a hazy sun in humid air. They watch the procession turn slowly from Memorial Drive into a magnificent Killian Court: bright yellow and lavender flowers, white canopy a garnish over a manicured platform, enormous speakers high up on each side that fill the court with music of a brass choir and later with President Jerome B. Wiesner's voice.

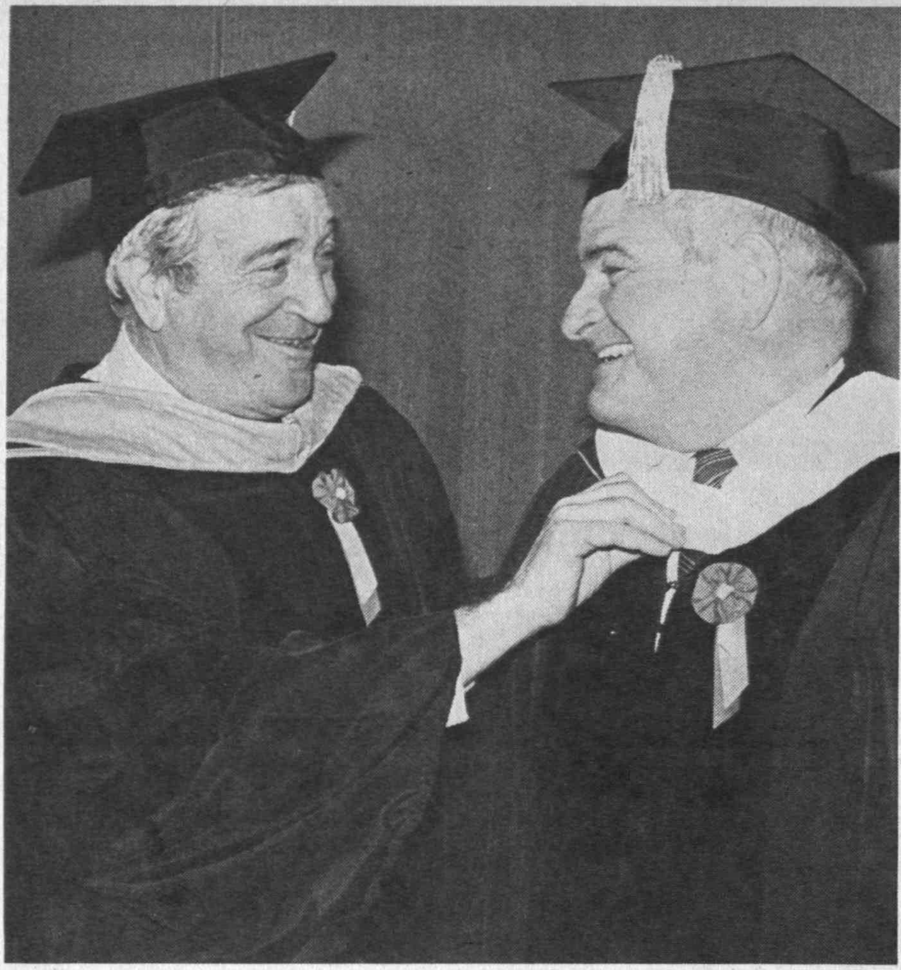
"Keep Moving"

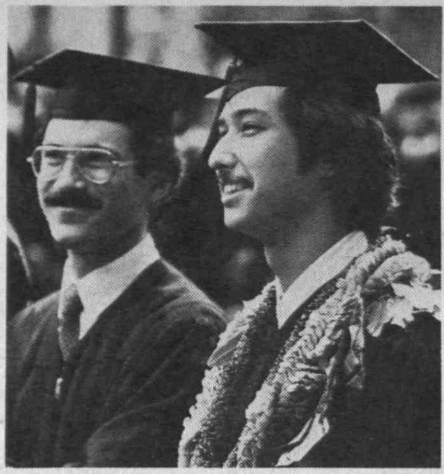
Sometimes he relates anecdotes:

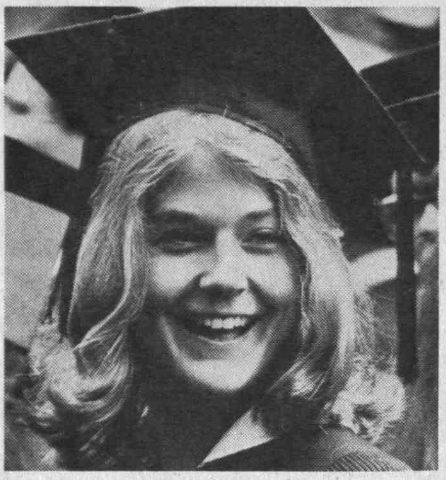
". . . A student told a member of the faculty that the most important thing he had learned at M.I.T. was from a remark I had made at his commencement. I was a bit startled — and obviously somewhat pleased — so I asked what it was that I had said. Apparently, as I handed him his diploma he stopped to say something to me but I said, 'Keep moving' — advice that he has been following ever since.

"That's not bad advice. I would only add that if you follow it, you should pause from time to time to see where you are going, and, perhaps even more importantly, where your good sense tells you that you should be going."

Birds provide a peaceful musical background. The sun's heat increases but a slight breeze is picking up. Rhododendrons ringing the court beg to be admired.







Dr. Wiesner's voice is strong, with unusual intensity. He looks to himself:

"As most of you know, I am also a graduating member of the Class of 1980 — no doubt the oldest, at least chronologically. I am not certain how many years it has taken me to graduate because, like other students, I have occasionally taken time off to see what was going on in other parts of the world. One thing is certain. Life at M.I.T. for me has been a continuous learning process with some of the best possible teachers, both students and faculty members."

And he expresses appreciation for the contribution families have made to support the students present.

"I congratulate all of you who are mothers, fathers, brothers and sisters, wives, husbands and sweethearts, young children, grandparents, and aunts and uncles. This is the one day of the year when our favorite expression, 'the M.I.T. family' takes on its deepest possible meaning. The old graduates used to have a saying, 'Tech is hell!' In recent years they have been saying, 'It's great, but it's expensive!' You — families and friends — have given both kinds of support to our students while they studied here."

Photographers jockey for vantage points up front; one has his tripod and 300-mm. lens smack in the middle.

President Wiesner reflects on the world:

"Why is the United States unable to develop its vast indigenous energy resources? It's clearly not for lack of technological ideas or solutions. Rather it comes from a paralysis due to a mixture of inhibitions on corporate initiatives, regional conflicts and questions of social equity — how to distribute the costs among us — resulting in an equation we have found impossible to solve."

In conclusion he suggests needed endeavors:

"I have found from long personal experience that trying to understand foreign cultures as a way of helping to resolve conflicts between our country and other nations is a particularly unpopular undertaking. But on the other hand, the successes are especially satisfying. I hope you too will find time on your agenda to challenge at least a few of the multi-cultural conventional wisdoms that must be bypassed to build a better world and have the courage to be a paradigm smasher if necessary."

Celebration and Completion

The procession to receive diplomas begins. Students' faces register a variety of emotions, from elation to sadness, the wistful element of goodbye. Carefully arranged stacks of diplomas slowly dwindle. One graduate records his experience on film as he carries a movie camera onto the platform.

It is a celebration and a completion.

A Senior Class gift of $1,750 is presented, to be used for electronic scoreboards for du Pont Gymnasium and the Alumni Pool.

Now the procession is reversed. Families hunt in the crowd for each other. The sky is suddenly turning ominous.

"There's dad! Dad!"

"We want to find my professor, not the food."

Tables of sandwiches and cookies are the center of the good-natured crush. One graduate holds his hat as a tray, stacked with food.

"Want a sandwich?"

"I've only got two hands, and I've got both of them working."

"Where's David?" "Ah oh, we lost him again."

The Henry Moore and Michael Heizer sculptures — and the Great Dome itself — become photo backdrops. The Heizer makes a perfect end table and seat; kids climb on it and cups rest.

Congratulations ring in the now-wet air.

Someone in a graduation gown is doing cartwheels in front of the band that is playing at the rear of the court.

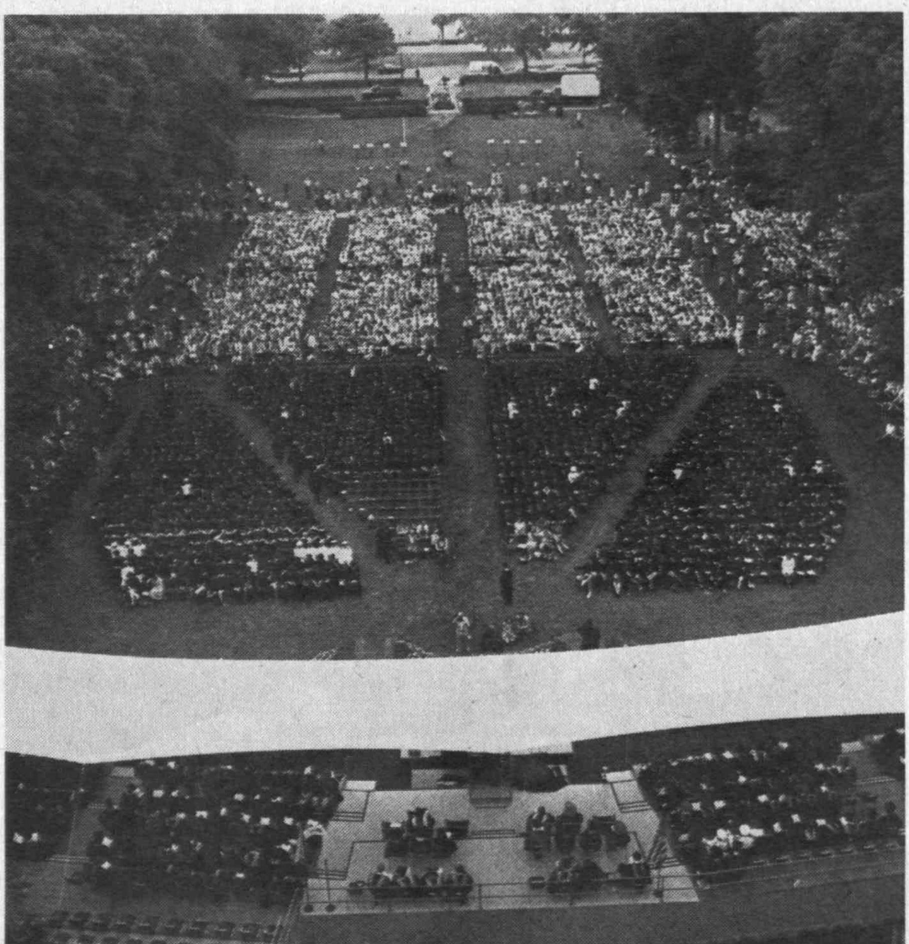
And then the crowd disperses, prodded a little by the dark sky. Bits and pieces of commencement will probably come floating through their memories for a long time. Crews of workers are already cleaning up, stacking chairs; stately Killian Court is quiet now. Raindrops start.— *M.L.*

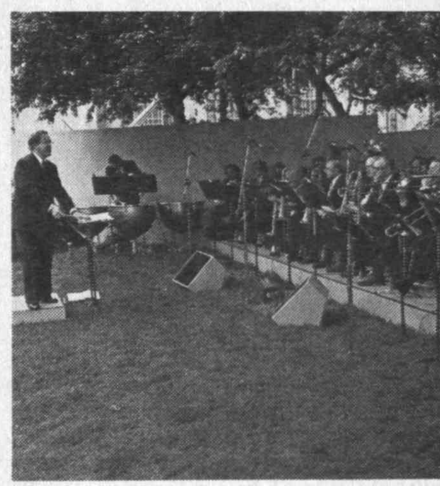
A Commissioning To Be Remembered

You couldn't fault the setting — the flight deck of the U.S.S. *John F. Kennedy* —nor the action in the foreground: commissioning into the Air Force, Army, Navy, and Marine Corps of 52 M.I.T. undergraduates in the Institutes's Reserve Officer Training Corps.

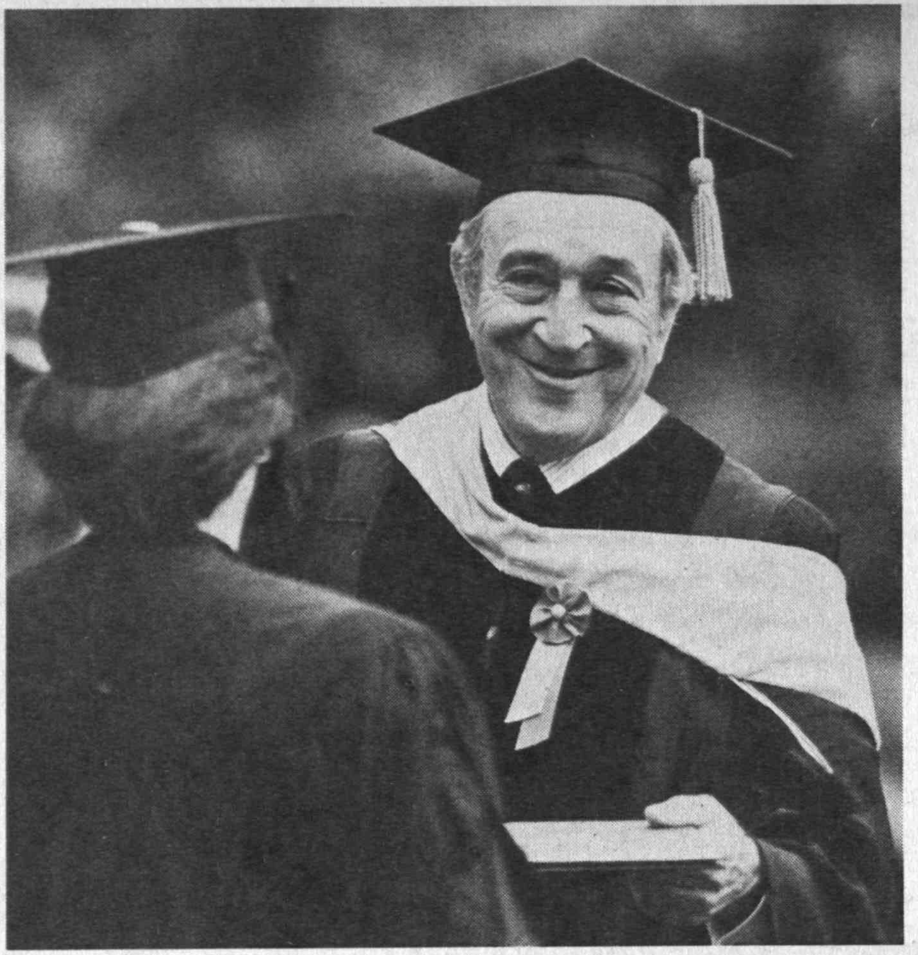
It was on Sunday, June 1, just two days after the aircraft carrier had served as reviewing stand for the parade of tall ships through Boston Harbor celebrating the city's 350th anniversary. The speaker at the ceremony was Vice Admiral Thomas J. Bigley, U.S.N., commander of the Second Fleet, who had been host to the Tall Ships dignitaries just two days before. With him on the deck were Captain John H. Sweeney III, who heads the Naval R.O.T.C. at M.I.T. (*shown administering the oath*), Walter A. Rosenblith, provost (*center in the picture*) and President Jerome B. Wiesner (*right*).

Commissions went to 16 Air Force cadets, 18 Army cadets, and 18 Navy midshipmen (one of whom entered the Marine Corps) — all members of the Class of 1980 scheduled to receive diplomas on June 2. Admiral Bigley took note of M.I.T.'s nearly unique position — one of the few U.S. universities with officer training programs in all four branches of the armed forces.

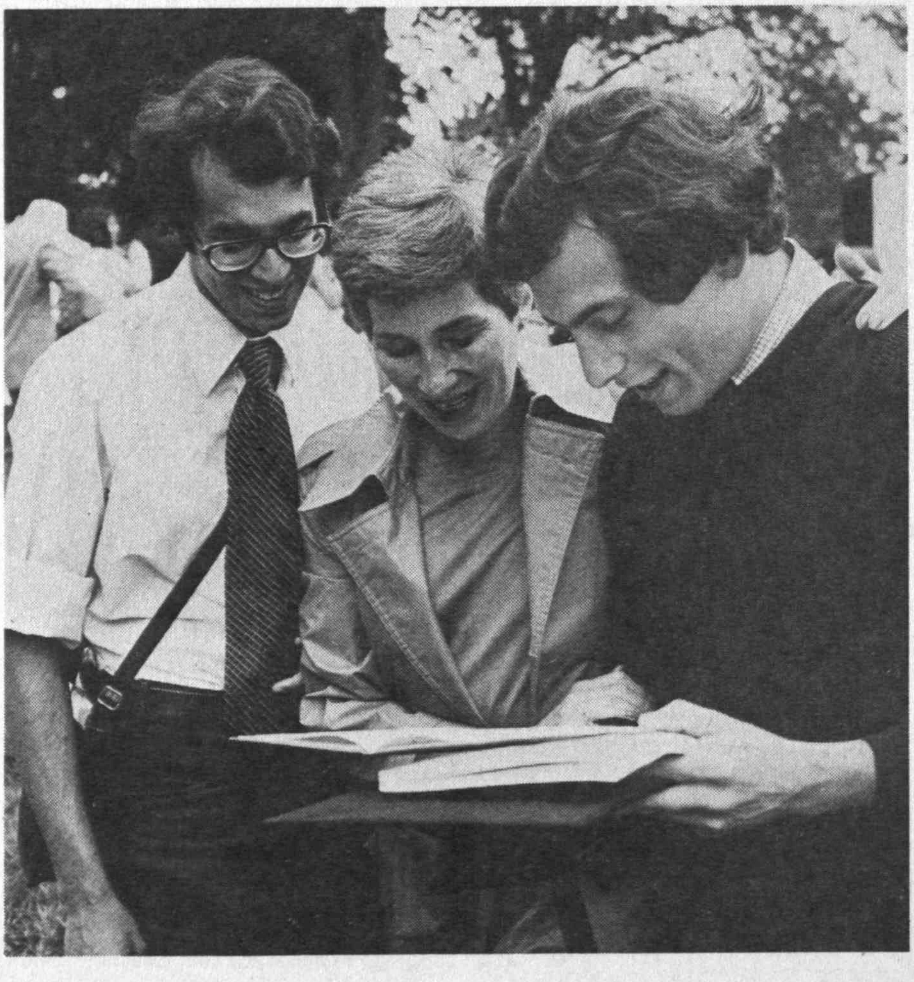




Commencement should be a time of good spirits — and clearly it was at M.I.T. on June 2. It was the last commencement to be celebrated by the partnership of President Wiesner and President-Designate Gray (left, opposite); for the graduates, as for them, it was a moment of rejoicing. And for those who had the planning chores, it was a moment of thanksgiving: grey skies withheld their threat until mid-afternoon. (Photos: James J. Snyder, '80; Calvin Campbell; John W. Lepingwell, '80)



To Steven L. Solnick, '81, editor-in-chief of The Tech, *commencement is "one of the special times when I feel nothing but pride for the school I am attending. The pomp, the solemnity, the happiness of the graduates, and the pride of the parents keep me motivated for months. I still get goosebumps thinking about it. M.I.T. becomes, for one brief morning, not a four-year taskmaster but rather a site for the vitally important exchange of knowledge between generations." (Photos: Owen D. Franken, '68, from Stock Boston)*



Expectations Versus Reality of M.I.T.: A Personal Reflection

by James A. Moore, '80

Five years ago, when I was in high school, I received an application from M.I.T. in the mail. I threw it out. M.I.T. was a place for eggheads, eccentrics, and other assorted weirdos who wore bottle-bottom glasses and had calculators strapped to their belts. Everyone knew that. I wanted nothing to do with the place. I was an athlete, an All-State runner, and college coaches were trying to recruit me. I did leaf through the M.I.T. bulletin long enough to find out that the Institute had a track program, but when I discovered that the record board at my high school held better performances, the bulletin joined the application in the waste basket.

All I wanted was a school with a top ranked track program; when I used college catalogs, I flipped first to "Intercollegiate Sports" and then to "Academic Offerings."

I decided to enroll at the University of Pennsylvania, where everyone seemed satisfied. My counsellors could point to "one more student attending a prestigious Ivy League institution." My track coach could point to one more protégé in a big time program. My parents — who left the entire college selection process up to me — wouldn't receive any flak from associates with children at Cornell or Yale. And me: I thought I'd be happy. Penn had a $250,000 Tartan track in a 60,000 seat stadium. It was the home of the world famous Penn Relays track meet, and its coaches were highly respected. The people I had met when I visited were friendly, and I liked the campus, which was located within three hours of my home. And, while Penn didn't offer undergraduate architecture, which was my main academic interest, the coaches assured me that it had "nearly the same thing."

I never even bothered to check.

After a year at the University of Pennsylvania, my certainty wavered. High school track and college track were worlds apart, and "nearly the same thing" wasn't anything like architecture. In high school, I had been the best runner on the team, and was treated as such. I decided what races I wanted to run, and if I felt sub par on the day of a tough workout, the coach rescheduled the workout. At Penn, I was one of eight or nine freshmen who had also been the best runners on their high school teams. We worried each week, not about which race we wanted to run, but if we would run any race at all. Everyone was as good as, or better than, I was, and if I felt lousy on the day of a tough workout, I dared not let the coaches find out. One sub par practice could dictate my race opportunities for the entire season.

I discovered too that college meant that school was no longer merely a prelude to three o'clock track practice. An impending test meant skipping practice or staying up late and trying to make do on four hours of sleep. Either way, my running performance suffered.

I went to Penn with a vague idea that architecture involved design studios, structures courses, and crit sessions, yet found myself taking figure drawing, French, and the history of art.

In the fall semester of my sophomore year, after a summer of mulling over my academic interest, I decided that the University of Pennsylvania was not going to make me into an architect and requested a spring term leave of absence to investigate a transfer.

M.I.T. was number one on my list. Design authorities considered the Institute's School of Architecture to be one of the finest in the country, and in the two years since I had last looked at a bulletin, the track records had improved somewhat. Besides, I had come to the conclusion that life was more than a 400 meter oval, and my voluntary withdrawal from the cross country team at Penn had proven that although I loved running, I didn't need organizational support. I came to Cambridge and visited the Architecture Department and the Track office, in that order, and decided that M.I.T. would fit my idea of what an architecture program should be.

Everything that greeted me upon my arrival in September of 1978 was new, and I eagerly looked forward to it. After about six weeks, the joy of novelty wore off.

M.I.T.'s hierarchy completely befuddled me, with 24 separate departments and a randomly heterogeneous mixture of graduates and undergrads. Living off campus for the first time in my life, I felt totally alone. My two roommates found themselves to be mutally incompatible, and to avoid antagonizing either, I avoided both. I spent long hours at the Institute, but after two months, knew less than half a dozen people, none very well. I never enjoyed returning to the cold, empty apartment at night, and I grew to hate solitary meals.

When I arrived at M.I.T., fresh from eight months of work in a design office, I was certain that I knew most of what there was to know about architecture. That first semester, my teachers seemed determined to convince me that I knew nothing at all.

To make up for the semester I took off, I enrolled for an extra heavy course schedule and decided to forgo track. I quickly found that school work took up all my time and was disturbed to discover when I wasn't doing work, I worried that I should be. I worked 14 hours a day, convinced that it was the "M.I.T. way." None of my preconceptions about architecture or M.I.T. had turned out to be correct, so I didn't even enjoy the work I did. I was unhappy, and couldn't figure out why, so I blamed the school. In December, when I received a note from the University of Pennsylvania stating that my leave of absence had expired, I just about decided to go back.

I barely made it through the first semester. Physically exhausted, I felt mentally tortured. Formerly, my personality had tended towards insouciance; now, for the first time in my life, I couldn't relax. I considered it ironic that my grades were uniformly excellent; it only made me wonder if they were worth the price.

My second semester was better than the first, simply because the weather got warmer rather than colder. I was still taking an overloaded schedule, and when my parents asked why I didn't take a lighter load and graduate a semester late, I questioned their sanity. The last thing I wanted to do, I told them, was stay at that "place" any longer than I had to.

One of the few people I got to know during my first year at M.I.T. was the Tech Catholic Community chaplain.

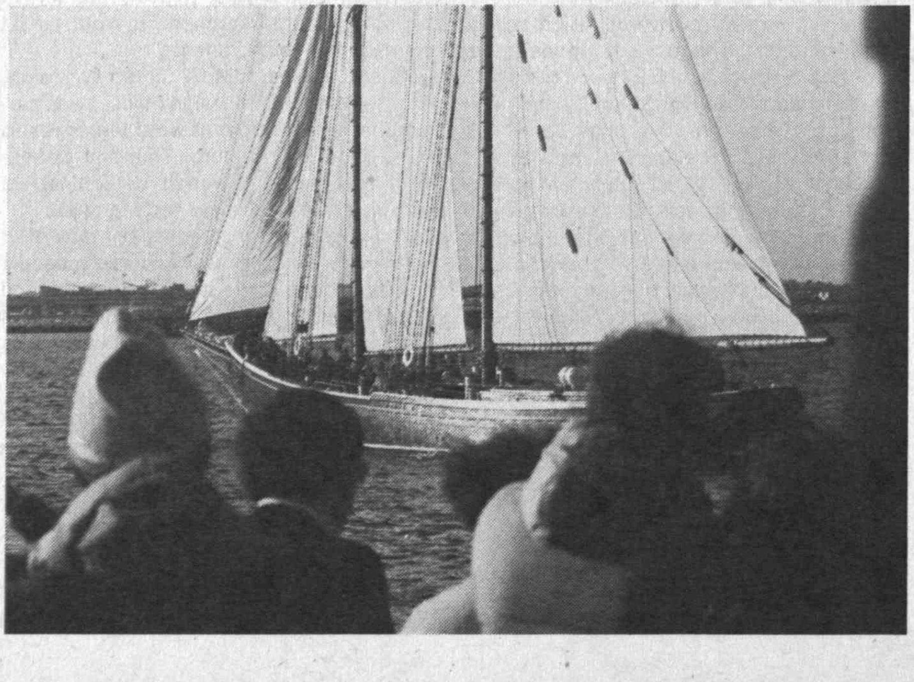
He told me that expectations can be dangerous if we refuse to exchange them for realities, and that often, things aren't what they appear to be. Gradually I came to see the truth in his words. M.I.T. hadn't turned out to be what I presumed it would be, and in holding on to my expectations, I had turned my back on reality. I began to see that M.I.T. actually was "what you made of it" as the admissions brochure had proclaimed; my disenchantment stemmed mainly from my personal attitudes.

Last fall, I scheduled a more comfortable work load around a series of courses that interested me, and soon discovered that I was actually enjoying my work. A new set of roommates brought enjoyment back to my living situation. I had done a lot of newspaper work in high school; now, I "found time" to write some stories for *The Tech*. During my junior year, I had skipped meals or worked through them. Now, I began to take time off during the day to lunch with some friends, attend a lecture, or simply read in one of the libraries. I started noticing that personalities existed on campus instead of ambulant ID numbers. Where I had previously resisted assimilation, now, almost in spite of myself, I was becoming a part of M.I.T.

Twelve months after I first arrived at M.I.T., my stated goal was merely to graduate. Suddenly, in late November, I realized that I would be foolish to leave. Just before the semester ended, I submitted a graduate application for a joint degree in architecture and science communication.

The day that my application was accepted, I felt the same excitement that I felt two years ago when my transfer was approved. M.I.T. might not be the place that I had expected, but I like what it is. I'm glad I'll be coming back.

M.I.T.'s Paul Neves, '83, edges Rod Garland of Brandeis to win the 800 meters in the first annual New England Division III Track and Field Championships held at Steinbrenner Stadium this spring. Colin Kerwin, '82, placed second in the 1,500 and third in the 5,000 meters. M.I.T. took fourth in the day's events, behind Westfield State, Coast Guard, and Fitchburg State. (Photo: Rick Parker)



A successful hunt for the tall ships: Bluenose II arrives in Boston harbor. Most of the world's fleet of great sailing ships was due in Boston on May 30 to mark the city's 350th anniversary. How many would be on hand by May 28? The M.I.T. Club of Boston made no promises, but excitement was high and over 1,600 members and guests turned out for a "tall ships hunt" – a three-plus-hour cruise of Boston harbor for which five vessels were finally chartered. Many tall ships, a brilliant sunset, and a full moon . . . it may have been the very largest activity ever attempted by an M.I.T. club in the history of the Alumni Association.

Robert J. Richardson, Sc.D.'54, senior vice president of E.I. du Pont de Nemours and Co., is a tall man, but President Jerome Wiesner has another reason for looking up to him during his visit at M.I.T. this spring. Leading a du Pont delegation, Dr. Richardson presented a $200,000 check for unrestricted support to the Schools of Engineering and Science. (Photo: Calvin Campbell)

Can Energy Technology Meet Energy Policy?

Though every college and university has courses in energy, every major school seems to have one unanswered question when it comes to managing research: how to bring technical and policy people together. Steven Rattner of the *New York Times* says M.I.T.'s Energy Laboratory is "widely regarded as one of the more successful," but its Director, Professor David C. White, admitted his frustration: technical and policy people bring different approaches, often difficult to reconcile, to energy questions. "I wish we could say that we have solved this problem, but we haven't," Professor White said. "The level of interaction is substantially lower than we'd like."

Frederic A. Holloway, Sc.D. '39, Vice President for Science and Technology at Exxon, thinks at least some of the problem lies with the government. "We've heard from more than one university that the government is good at supporting technical studies but not very good at supporting policy studies," Dr. Holloway told Mr. Rattner.

Engineering for American Indians

Thomas F. Dawson, a member of the Cherokee tribe who's on the engineering staff at Charles S. Draper Laboratory, believes there are ten American Indians studying this year at M.I.T., and he wants to organize a local chapter of the American Indian Science and Engineering Society. AISES has two purposes, he says. "We need to increase the number of Indian scientists and engineers, and we need to provide the Indian community with the science and technology they need to develop and manage their lands and resources.

The Other Side
John Molitoris

Yes, But Is It a College?

John Molitoris, '80, will be a graduate student in nuclear physics at Stanford Universitty in the fall.

My roommate stood in the door gaping at me, "C'mon! You'll never get to do it again." I nodded in reluctant agreement, shut the textook before me and grabbed my coat. My roommate is a graduate student in materials science and engineering who finished his S.B. in three years and spent the fourth year working on an S.M. He had essentially finished his thesis two days ago and so had I. We were going over to our fraternity to let our pledge brothers know we were done and to see how they were faring. (Actually we knew that none of them was finished; in fact, some were just starting. We just wanted to rub in the fact that we were finished, since theses were due the next day.)

I was not surprised to find some seniors sleeping, others out on the town and only a few working late (after all, this is a fraternity). Max was working late, so we decided to pay him a visit. He knew we were done, we knew he was not, so instead of rubbing anything in, we just talked.

Four years at M.I.T. are almost over and we had all come a long way. My attention drifted from the conversation to a picture calendar from some southern university. Now here was a real college: 50 percent of the student body was female, there were football games, cheerleaders, school spirit, and even people who major in cultural geography, Renaissance literature and Egyptology. We had sacrified these things four years ago when we decided to come to M.I.T.; however, and none of us regretted it. M.I.T. is simply M.I.T.; it has provided us with a solid background and enabled us to choose a direction. Max did have an interesting comment to all this: "Sure M.I.T.'s an *institution*, but is it a *college*?"

It is worthless to look at this question in the general sense as M.I.T. takes on a different perspective for each individual. For me, "the 'tute" has taken on a split personality; it is both an institution and a college. M.I.T.'s serious scientific and technical personality dominates our academic life. It impresses professionalism on us to the extent where a few students rebel and advocate anti-professionalism (they hate their vocations). These are extreme cases and most of us appreciate what M.I.T. is and the impact it will have on the rest of our lives.

M.I.T., the college, exists, but we save it for weekends and the night after a test. We have our drinking contests, our Greek Week (complete with pledge-powered chariot races), and even the big "home-coming" game. From what I have seen, when M.I.T. students work, *we work*, and when we play, *we play*. We have come to know the night life of Boston and Cambridge as part of our college life. Indeed, the whole Boston area is our "hang out." The Harvard fellow in the three piece suit will sneer at us during a mixer, but we know that we are the engineers of our world, and his! We can roll up our sleeves, get the job done, and do it well. Admittedly though, M.I.T. does have its anomalies.

One day I was walking in the basement corridor in Building 6 after a meeting with a professor. It was a good day; the Institute did not seem grey at all. I remember thinking what a normal place this was. Then I heard this "beep, beep" in back of me. Turning around and expecting to see the roadrunner, I was jolted back to reality by the sight of a short person rounding the corner on a skateboard. He was garbed in grimy jeans and a torn shirt. On his head was a beanie adorned with a propeller. He was precariously balanced on his board by a stack of books in one arm and a huge calculator affixed to his belt. So M.I.T. does have its anomalies, we all know that, but the fact is that most of us realize that our calculator is not a security blanket and we do not need ten-digit accuracy in the everyday world.

We find anomolies everywhere though. I can recall a hot summer day when I was playing frisbee in Killian Court. The frisbee landed close to the Henry Moore sculpture, and as I went to retrieve it, I noticed a group of tourists photographing the sculpture. There was a paunchy middle aged gentleman who was dressed in a flowered shirt, shorts, straw hat, black socks, and sandals. He knelt in front of the sculpture, but before the picture could be taken, he had a brilliant idea. He reached into his lunch bag, grabbed a huge pickle, and stuck it in his ear. Then his wife interrupted, grabbed another pickle and stuck it in her ear. She posed with her chin on his head (both were still armed with pickles). A number of strange acts with pickles followed, but these people made the anomalies at M.I.T. seem like the guy next door.

Indeed, we do not sneer at our anomalies; we go our own way and let people go their own way. Like the incident in Electromagnetism II last semester. In the middle of a lecture, this fellow walks in wearing a pair of orange antlers. He sits down, then pulls out a two foot pencil and begins to take notes. About five minutes later he drops the pencil in disgust and takes his ball point pen out of his pocket. The lecturer did not miss a syllable. In general, people are serious here and there is no reason to ridicule someone for working on a computer until 5 a.m. when you know you will have to do it the following night. I guess all this has become part of us and in a short time will be over.

In a few weeks, Walker Memorial will sit empty and finals will be but a memory. For the first time in four years, the seniors will be caught up and we won't even have another semester to think about. Each of us has made M.I.T. as much of a college or an institution as we wanted. We leave with mixed feelings, but beneath it all is the subtle realization that we have worked hard and we have completed four years at one of the finest scientific and technical institutions in the world.

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Left to right, top to bottom:
Dallas: *Provost Walter A. Rosenblith greets Cecil H. Green, '23; Mrs. Margaret McDermott, President Jerome B. Wiesner, and Mrs. Green in the foreground.*
Dallas: *President-Designate Paul E. Gray, '54, with President Wiesner, Mr. Green, and Howard W. Johnson, Chairman of the Corporation.*
Dallas: *Edward O. Vetter, '42, William J. Sherry, '21, and John Lawrence, '32.*
New York: *S. James Goldstein, '46, with Dr. Gray, Mrs. Cook, and J. Franklin Cook, '31.*
Cambridge: *The $2.5 million triumph celebrated in Walker Memorial.*

Leadership Campaign Completed: A Success in Dollars, Spirit, and Commitment

Top to bottom, left to right:
Cambridge: *Howard W. Johnson, Chairman of the Corporation, with Bernard H. Nelson, '35, and Mrs. Nelson*
Cambridge: *Paul L. Helmuth, co-chairman of the campaign, and Kenneth J. Germeshausen, '31.*
New York: *Mr. and Mrs. George J. Leness ('26), Chancellor Paul E. Gray, '54, and Mr. Johnson.*
Cambridge: *Philip D. Blanchard, '24, and President Jerome B. Wiesner.*
New York: *Provost and Mrs. Walter A. Rosenblith with Lester Wolfe, '19.*

Five years of the M.I.T. Leadership Campaign officially concluded on April 22. The final tally: contributions totalling $250.2 million. Successful well beyond the $225-million goal the Institute set for itself in 1975, the Campaign raised the third largest amount ever raised by a college or university in a single effort.

There were more than 32,000 donors from among alumni, friends, foundations and industrial organizations — testimony "to the unrivaled generosity of the Institute's benefactors," said Howard W. Johnson, Chairman of the M.I.T. Corporation who headed the Leadership Campaign.

At a meeting of 550 alumni and friends hosted by the M.I.T. Alumni Council on April 22, Mr. Johnson, President Jerome B. Wiesner, and Chancellor Paul E. Gray, '54, formally announced the successful conclusion of the Campaign and discussed its importance and the future endeavors it had made possible. Then they journeyed to six major cities across the United States to meet with alumni and friends, bringing them detailed news of the Institute's success that their help has made possible.

There was a sense of history permeating Walker Memorial that evening. The group obviously included many old friends; a portrait of President Wiesner was on display; Walker Memorial itself is a symbol of times past at M.I.T., reflecting links with the corporation, alumni and faculty.

At the head table on April 23 sat the same group that had attended the Campaign's beginning five years ago when the fundamental purpose of the Campaign was defined — to undergird M.I.T.'s financial stability; to maintain the Institute's high quality of teaching and research; to enhance further the education of tomorrow's leaders. Now those objectives have been achieved.

The Campaign total includes $68.1 million in new endowment, $60.7 million for facilities, and $121.4 million for new programs and for current use. Gifts include $93.1 million contributed by individuals, $80.8 million from foundations, and $74.7 million from corporations.

Chancellor Gray noted that the 1980s may not be "the best of times for higher education, for science and technology or for basic research.

"They are the only times we have, however, and we can use them, in the traditions of M.I.T., to pursue quality and innovation and to make bold moves that will ensure 'world space' for the Institute in the future," he said.

Dr. Wiesner spoke of unexpected benefits of the Campaign:

"One pleasant surprise of the Campaign has been the extensive conceptualization, development and integration of academic programs which have resulted from our examination of the Institute's potential capabilities and needs.

"Prime examples of the results of such dialogues and reassessments have been the development of a very extensive energy program, tremendous growth of the Institute's activities in the health-related sciences, and the ever-widening activities in the information sciences — both living and man-made. It is interesting to note that in little more than a decade, M.I.T.'s life sciences and health-related teaching and research activities have grown from embryonic programs to the point where they now represent approximately one-third of the total on-campus activities."

Howard Johnson warned of inflationary pressures while looking beyond finances to other goals:

"Uncertain economic conditions made [our] initial goal both more difficult to reach, on the one hand, and in some senses inadequate, on the other hand, because of the impact of inflation. While we are pleased to have exceeded the initial target, these inflationary pressures make it essential that we push even harder to secure the continuing goals of our ongoing development program.

"Beyond what is denominated in dollars is that which is denominated in spirit and commitment. And above the effort, energy, and relentless requirement of achieving our goal that this Campaign had embodied, there stands that loftier goal that makes this whole matter of mythic significance: to so advance M.I.T. in seeking to meet its responsibilities for education and research and service that the lives of men and women, here now, and yet unborn, will be improved and uplifted and made more worthy as reflections of decency, accomplishment, and achievement."

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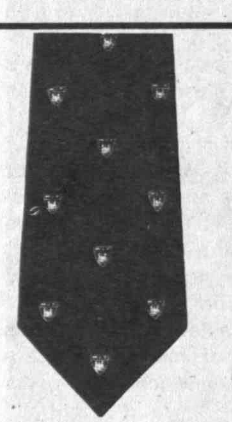

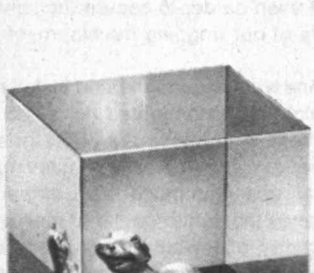

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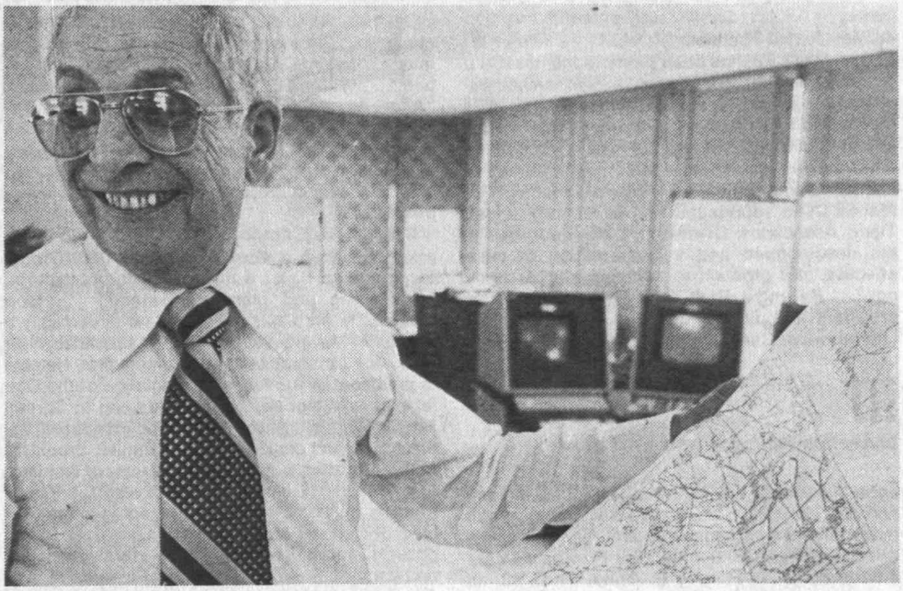

When he retired this spring from his job as chief meteorologist at Logan Airport in Boston, Anthony E. Tancreto, S.M.'45, took home with him two plaques from the National Weather Service, recognizing his success in forecasting two major storms in 1978. There were also some other kind of memories: in 1976 he and his Logan crew forecast 110-mile winds in Hurricane Belle – but they missed: the winds were only 65 knots. (Photo: Peter Southweck from the Boston Herald-American)

The Man Who Changed "Partly Cloudy" to "Partly Sunny" Retires from Forecasting

Anthony E. Tancreto, S.M.'45, has suddenly stopped worrying about hurricanes, wind, fog, rain, snow, and all those other phenomena of weather which plague New England: he retired on March 31 as chief meteorologist at Logan Airport, after 35 years as a weatherman.

Among his major achievements is changing the phrase "partly cloudy" to "partly sunny" in Weather Bureau parlance. That happened while he was forecasting the weather for Atlantic City during one particularly rainy summer, he recalled this spring for Harold Banks, *Boston Herald-American* staff writer.

Mr. Tancreto started out to be a mathematician at Tufts University; that was changed when the Navy sent him to M.I.T. during World War II. He found the weather suited him, and after a stint for the Navy on Midway Island in the Pacific he went to work for the National Weather Service — and sometimes for private meteorologists — in Bermuda, New York, Boston, Atlantic City, Washington, and St. Louis.

A native Bostonian, Mr. Tancreto likes New England's reaction to the weather. In New York, he told Mr. Banks, "if we forecast snow and there was no snow, we'd be crucified." But in New England, he says, if snow doesn't come they just say, "Thank God, we missed it." "They realize there was a justification for our forecast; they understand we had to let them know the potential for a heavy snow was there."

I

Civil Engineering

Gregory B. Baecher, Ph.D.'72, has been promoted to associate professor in the Department; his research has been directed toward an application of probability theory and decision analysis in geotechnical engineering. . . . **Robert G. Dean,** Sc.D.'59, Unidel Professor of Civil Engineering and Marine Studies, University of Delaware, Newark, has been elected to membership in the National Academy of Engineers. . . . **Rodney P. Plourde,** Ph.D.'71, is presently principal engineer of Fay, Spofford and Thorndike, Inc., Fall River, MA. . . . **S. Bruce Smart,** S.M.'47, has been elected a director of the Celanese Corp. . . . **Thomas H. Asselin,** S.M.'66, reports that he "has recently become senior partner in the law firm of Peterson, Young, Self and Asselin, Atlanta, Ga., specializing in construction law and government contract law."

Richard J. Dauksys, S.M.'70, has been appointed Manager, Technical Development of the Dexter Corp., Windsor Locks, Conn. . . . **Harry N. Wallin,** S.M.'37, notes, "I retired from 28 years active duty in the Civil Engineering Corps of the United States Navy in 1968 and joined Bechtel Corp., San Francisco, Calif. After ten years with Bechtel, I retired again in 1978 and have been enjoying retirement by travelling, playing golf and pursuing other hobbies with my wife of 38 years." . . . **Roger Foott,** Sc.D.'73, is currently a senior engineer at Dames and Moore, Los Angeles, Calif., specializing in soil mechanics.

II

Mechanical Engineering

Professor **Ernest G. Cravalho's** interests in the medical applications of mechanical engineering, already recognized by his appointment as associate director of the Harvard-M.I.T. Division of Health Sciences and Technology, will now be utilized as well by the Whitaker College of Health Sciences, Technology, and Management; he's been named an associate director of the college by its director, Dr. Irving M. London.

Steven F. Manzi, S.M.'77, is presently a mechanical design engineer at Hewlett-Packard Corp., Waltham, Mass. . . . **Joseph Fu,** S.M.'65, reports that he has "started a company in high-speed matrix impact printing technology, manufacturing the OEM high-speed matrix printhead, 200 CPS. . . . **Martin Alexander,** S.M.'73, has been named vice president of Lewis S. Goodfriend and Associates, consulting engineers in acoustics, Cedar Knolls, N.J. . . . **Ernest B. Gardow,** S.M.'58, professor at the University of Hartford's College of Engineering, has been elected a vice president of the American Society of Mechanical Engineers (ASME).

Laurance G. Coffin, S.M.'56, has been elected second vice president of the American Associa-

With her new Henry L. Doherty Professorship, Dr. Sallie Chisholm (center) of the Department of Civil Engineering will expand her research into details of the individual cell behavior associated with marine phytoplankton growth. The photograph was made as Walter A. Rosenblith (left), provost, gave Professor Chisholm her letter of appointment, observed by Frank Professor E. Perkins, '55, head of the department. (Photo: D.J. Dudzik from Tech Talk)

tion for Textile Technology (AATT). . . . **Peter W. Huber,** Ph.D.'76, has been promoted to associate professor in the Department of Mechanical Engineering at M.I.T. His expertise lies in fluid mechanics and the thermal sciences and he has already developed an international reputation for his work on fluid-structure interactions related to nuclear reactor safety. . . . **Vijayakumar A. Tipnis,** Sc.D.'65, reports that he has recently formed Tipnis Associates, Cincinnati, Ohio, dedicated to the development and implementation of cost-effective and productive manufacturing technology. . . . **Byiung J. Park,** S.M.'61, is currently vice president and director of the Consumer Testing Laboratories, Canton, Mass.

III
Materials Science and Engineering

John A. Crichton, S.M.'38, president of Crichton and Co., Houston, Tex., a petroleum and minerals management and consulting firm, was elected a director of Transcontinental Gas Pipe Line Corp., a subsidiary. . . . **Harvey E. Cline,** Ph.D.'62, an inventor at the General Electric Research and Development Center, Schenectady, N.Y., has been honored for having earned his 75th patent. Research by the team in which he works has been cited in more than 200 technical journals, with many references to a semiconductor processing technique called thermomigration. . . . **Thomas W. Eager,** Sc.D.'75, has been named associate professor in the Department of Materials Science and Engineering at M.I.T.; his research has focused on the physics and chemistry of welding. . . . **Rowland M. Cannon,** Sc.D.'75, has been promoted to the rank of associate professor in the Department.

Raj N. Singh, Sc.D.'73, has joined the General Electric Research and Development Center, Schnectady, N.Y., as a ceramicist. . . . **Frederick S. Blackall,** S.M.'75, was elected to the Board of Directors and named assistant secretary of the Taft-Pierce Manufacturing Co., Providence, R.I. . . . **Jack H. Vernon,** S.M.'54, has been named senior vice president and Eastern regional manager of Heidrick and Struggles, Inc., an international executive search firm. He will be responsible for the firm's offices in New York, Boston and Greenwich.

IV
Architecture

Sylvia Reay, M.Arch.'40, reports, "I recently enjoyed a "mini-reunion" with **Francis Meisch,** M.Arch'40, and his wife Elaine when they were in San Francisco. All of us are still active professionally and looking forward to future work. . . . **Bernard P. Spring,** M.Arch.'51, is currently chairman, Site Planning and Design Exam Committee, National Architectural License Examination. . . . **William E. Roesner,** M.Arch.'66, writes, "After an eight-year association with the Architects Collaborative in Cambridge, I have hung out my shingle and been swamped with work designing and building a wide variety of smaller new and remodelling projects and am enjoying every minute of it.

Charles B. Thomsen, M.Arch.'63, has been elected executive vice president of CRS Group, Inc, Houston, Tex., a major firm in architecture, engineering and planning systems. . . . **Bob Mayers,** M.Arch.'62, writes that he is currently a partner in Mayers and Schiff and Associates, New York, N.Y., an architectural planning firm. He also is president of the Alumni Association of the College of Architecture, Art and Planning at Cornell University and adjunct associate professor of architecture and design at Pratt Institute, Brooklyn, N.Y. . . . **Walter A. Rutes,** '51, director of architecture for Holiday Inns, Inc., and **Everett A. Glendening,** M.Arch.'54 have been elected to the College of Fellows of the American Institute of Architects. **Hugh Shepley,** '59, currently principal architect of Shepley, Bulfinch, Richardson and Abbott, Boston, has been elected a trustee of University Hospital, Boston.

V
Chemistry

Charles Berney, S.M.'54, notes, "I directed the M.I.T. Community Players' production of Gilbert and Sullivan's 'The Mikado,' which played to packed houses for two weeks last August." . . . **David A. Ucko,** S.M.'72, has accepted the position of research coordinator, Museum of Science and Industry, Chicago, Ill. . . . **Joanna (Ferber) Shulman,** S.M.'65, received her M.D. degree from New York Medical College this June.

Edward R. Kane, Ph.D.'43, recently retired as president of E.I. du Pont de Nemours and Co. and has been elected director of Texas Instruments, Inc., Dallas, Tex. . . . **George J. Thomas Jr.,** Ph.D.'67, is professor and chairman of the Chemistry Department at Southeastern Massachusetts University and director of a research laboratory at the university. . . . **Charles Starks,** Ph.D.'59, is presently director of exploratory chemicals research at CONOCO, Inc. . . . **Arthur Obermayer,** Ph.D.'56, recently displayed his newest invention — a toxic vapor detector — at Boston Museum of Science's "Inventors Weekend."

Robert Kohrman, Ph.D.'69, professor of chemistry at Central Michigan University, has been selected for an award under the University's Professor/Research Associates Program. He is pursing a project titled "An Investigation of the Photochromic Behavior in the Alkanesulfonate Esters of 3-Hydroxyflavone" and will also investi-

Toward More Economical Night-Time Photography

Three M.I.T. alumni — Freeman D. Shepherd, '58, Andrew Yang, Ph.D.'57, and William Ewing, '67, are credited with key roles in developing a new focal plane shutter system for infrared television cameras; the result, says the Air Force Electronic Systems Division at Hanscom Air Force Base, Mass., where all three are staff members, may be a ten-fold reduction in the cost of such equipment.

Infrared sensor cameras reproduce images of heat rather than light; they're used for surveillance and target indentification, weapons guidance, and satellite mapping. And since they cost as much as $100,000 each, the successful research at Hanscom is an important achievement.

Air Force studies of more economical ways to achieve night-time imagery began in the early 1970s. The focal plane technology on which Drs. Shepherd and Yang worked was a significant part of the effort. Dr. Ewing, meanwhile, was working successfully on a video infrared camera that is compatible with commercial television and several existing military sensor systems.

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gate the phenomenon of photochromism.

The memory of **Henry A. Hill,** Ph.D.'42, who died on March 17, 1979, after a distinguished career in chemistry and professional service, has been honored by the Northeastern Section of the American Chemical Society with the establishment of the Henry A. Hill Memorial Award, and its first presentation was on March 13, 1980, to Anthony C. Hill, a reporter for WGBH-TV, Boston.

John M. Deutch, '61, who was on leave from M.I.T. to be under secretary of the U.S. Department of Energy, has returned to his academic pursuits as Arthur C. Cope Professor of Chemistry. He went to Washington in 1977 when nominated by President Carter to be director of the Office of Energy Research.

Professor Christopher T. Walsh, who holds faculty posts in both chemistry and physics, is associate director of the new Whitaker Collge of Health Sciences, Technology and Management.

Edward Allein Heintz, Ph.D.'57, manager of carbon and graphite research for Airco Carbon, Niagara Falls, N.Y. has been awarded the 1980 Jacob F. Schoellkopf medal "for his contributions to a better understanding of the principles of the graphitization process and the application of those principles to the manufacture of artificial graphite."

VI

Electrical Engineering and Computer Science

Arthur J. Schneider, Ph.D.'59, has been named staff vice president of Sperry Research Center, Sudbury, Mass., a subsidiary of Sperry Corp. . . . **Robert Morre,** Ph.D.'71, is currently director of engineering and manufacturing for the Measurement Systems Division of Gould, Inc. . . . **Roger J. Sudbury,** S.M.'63, is associate group leader of the Experimental System Group at M.I.T. Lincoln Laboratory, responsible for the development of solid state components for phased array radar application. . . . **Cynthia Kozin,** S.M.'58, has been appointed section head and supervisor of the Reconnaissance and Surveillance Systems Division's software engineering staff of the Eaton Corp., AIL Division, Deer Park, N.Y.

John I. Makhoul, Ph.D.'70, has been elected fellow of the Institute of Electrical and Electronics Engineers "for contributions to the theory of linear prediction and its applications to spectral estimation, speech analysis, and data compression. . . . **Daniel E. Noble,** '38, designer of the first mobile FM communications system, a former vice chairman of Motorola, Inc., and professor of mathematics and electrical engineering at the University of Connecticut, died February 16, 1980. In addition to his wide range of scientific and engineering interests, he was for many years engaged in what he called "experimental painting." His talents as an artist were recognized internationally, and today his paintings are on permanent display in five universities and three technical institutes.

Eric S. Beckjord, S.M.'56, has been appointed to the newly created position of deputy director for science and technology at the Department of Energy's Argonne National Laboratory, Argonne, Ill. He will be responsible for overseeing all the scientific and technical programs at the firm, with particular responsibility for the applied research and development programs. . . . **Jack M. Aiello,** S.M.'74, reports that he is currently a training manager for the Intel Corp. . . . **Wesley W. Pendleton,** S.M.'40, reports "I retired as of May 1, am a life fellow of IEEE and am scheduled to teach next fall at Ferris State Collge. I have written a book and have earned 16 patents."

Eric S. Beckjord

VI-A

Cooperative Course in Electrical Engineering and Computer Science

This year's new VI-A class falls just two short of equalling VI-A's largest class ever to enter the program — that being 100 in 1979. This year 98 applicants were finally selected by the cooperating companies from among the 169 applicants. However, this year did see the largest number of students apply since the program began in 1917, representing 42.7 percent of the current sophomore class registered in Course IV.

Beginning this June students will go to three new VI-A locations. Three will start their first assignments at Medtronic, Inc., Minneapolis, Minn. One will begin with IBM Corp.'s General Technology Division, Burlington, Vt. Another, who has done his two undergraduate work assignments at Motorola's Schaumberg, Ill. facility, will transfer to the Codex Corp., Mansfield, Mass., a subsidiary of Motorola, for his two graduate assignments. All other students will be going to company locations previously having students from the program.

This has been a prime year for M.I.T. graduates seeking employment. Many VI-A's have reported how enthusiastic companies are about the experience they bring into the marketplace from their affliliation with the program.

Mark T. Fuccio, '80, has accepted a position with Phillips Laboratories, Briarcliff Manor, N.Y. Phillips Laboratories is a participant in M.I.T.'s three-year-old Engineering and Internship Program (EIP) which now runs in parallel with and is based on IV-A. . . . **Donald L. Brinkley,** '79, will be associated with Magnovox Data Systems, Falls Church, Va.

Since last reporting, a number of VI-A alumni/ae

Caspary Professorship to Benedek

M.I.T.'s first Alfred E. Caspary Professor of Physics and Biological Physics is George B. Benedek, who has made pioneering contributions to medical physics since joining the Department of Physics faculty in 1961.

Mr. Caspary, who studied at M.I.T. with the Class of 1898, was widely known for his philanthropy devoted to the advancement of medicine; the professorship is based on a grant made by Mr. Caspary's estate for M.I.T. research in fields having human medical implications.

Professor Benedek's contributions to physics are wide-ranging, from the properties of magnets and fluids and techniques of spectroscopy to the optical qualities of the human eye. He is a lecturer on physics at Harvard Medical School, a consultant to the research unit of Retina Foundation, and a principal in the Harvard-M.I.T. Division of Health Sciences and Technology.

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have signed our VI-A office guest book: **Michael J. Callahan,** '62, vice president — operations with Monolithic Memories; **Arthur C. Chen,** '61, with General Electric Corporate Research and Development; **Edward C. Giamio,** '74, with Hewlett-Packard's Colorado Springs Division; **Bradford E. Hampson,** '77, with PR1ME Computer; **Jeffrey D. Kurtze,** '71 with Lincoln Laboratory's technical staff; **Jeffry R. Long,** '74, with TI/Dallas; **Takashi Mitsutomi,** '52, with HYCOM, Inc.; **Scott C. Munroe,** '76, on Lincoln Laboratory's technical staff; **Charlene C. Nohara,** '79, with Xerox; **Kevin D. Stoddart,** '71 with Watkins Johnson; **Jack L. Walker,** '62, technical director, ERIM in Michigan; and **John D. Williams,** '76, Hewlett-Packard visitor at California Institute of Technology.

Two of our current VI-A students were among those awarded National Science Foundation Graduate Fellowships. They are **Charles A. Freeman,** '80, associated on VI-A with Hewlett-Packard Laboratories, Palo Alto, Calif., and **Steven K. Ladd,** '81, whose VI-A affiliation is with General Electric's Computer Management Operations Division, Bridgeport, Conn. — John A. Tucker, Director, Course VI-A, Room 38-473, M.I.T.

VIII

Physics

Roy F. Schwitters, Ph.D.'66, a leader in experimental high energy physics, has received the Alan T. Waterman Award "for his outstanding contributions in several areas of physics which have had, and will continue to have, a profound influence in an important field of science."

Three members of the department's community were elected to the National Academy of Sciences last April: **George W. Clark,** Ph.D.'52, professor of physics at M.I.T.; **Cyril M. Harris,** Ph.D.'45, Charles Batchelor professor of electrical engineering and professor of architecture at Columbia University; and **Robert N. Noyce,** Ph.D.'53, chairman of the Intel Corp., Santa Clara, Calif.

William W. Happ, S.M.'47, writes "I have been elected a member of the National Academy of Engineering [Mexico], and have served two years as chairman of the Department of Electronics and Communications at the University of Guana Juato.

X

Chemical Engineering

Maurice F. Granville, S.M.'39, will retire on November 1 as chairman of Texaco, Inc., White Plains, N.Y. . . . **William Lees Bulkley,** M.S.'40, of Sun City, Ariz., passed away on March 10, 1980. . . . **Donald B. Anthony,** Sc.D.'74, has been appointed manager of synthetic fuels development at the Sohio Co., Cleveland, Oh., responsible for leading the commercialization of alternate energy technologies such as oil shale recovery and coal conversion processes. . . . **Jan W. Mares,** S.M.'60, has been named vice president and general manager of the Ethylene Oxide Division of Union Carbide Corp., New York, N.Y.

Thomas F. Seamans, S.M.'59, has been appointed to the position of manager of manufacturing for Ionics, Inc., Watertown, Mass. . . . **Charles N. Satterfield,** Sc.D.'43, recently wrote a book entitled *Heterogeneous Catalysis in Practice,* published by Mc-Graw Hill; the publisher describes it as intended for professional scientists or engineers working with solid catalysts in the laboratory, pilot plant, or commercial production. . . . **Chittaranjan R. Mitra,** S.M.'50, director of Birla Institute of Technology and Science (India) has been elected chairman of the Association of Commonwealth Universities (ACU), London.

XI

Urban Studies and Planning

William J. Cairns, M.C.P.'67, reports, "I have formed in 1972 the Edinburgh (Scotland) environmental consulting organization of W.J. Cairns and Partners which continues to expand services for industry and government, playing a major consultancy role in North Sea oil and related development. WJCP has more recently won contracts in the Far East and Mid East, and are pleased to report that they are experiencing a period of in-depth development, broadening horizons, and supporting a staff of 50 professionals." . . . **Mathew Thall,** M.C.P.'75, is currently senior staff planner and coordinator of the Pilot Modernization Program at the Cambridge Housing Authority. In his "spare time" he serves as president of the Fenway Community Development Corp., which is developing solar multi-family housing for low and moderate income people.

James R. Warring, M.C.P.'71, is presently assistant to the chief executive officer of John Portman and Associates, Atlanta, Ga. . . . **James E. Wallace,** Ph.D.'72, is currently managing a national evaluation of the HUD Section 8 Leased Housing Program (existing housing and new construction) with Abt Associates, Inc. . . . **George N. Kurilko,** Ph.D.'69, has joined the firm of Dames and Moore, engineering and environmental consultants, Los Angeles, Calif., as a senior planner. . . . **William L. Porter,** Ph.D.'69, who retires this summer as dean of M.I.T.'s School of Architecture has been elected a Fellow of the American Institute of Architects, for his notable contribution to the advancement of the profession.

XV

Management

Donald L. Isaacs, S.M.'74, was elected one of the senior vice presidents of Baybanks, Inc., Boston, Mass. . . . **Oliver C. Boileau Jr.,** S.M.'64, has been appointed president and director of General Dynamics Corp., St. Louis, Mo. . . . **Ray W. Ballmer,** S.M.'60, president of Amoco Minerals Co., was named to the additional post of executive vice president of Cyprus Mines Corp., Chicago, Ill. . . . **Hugh E. Witt,** S.M.'57, was elected director of Data-Design Laboratories, Cucamonga, Calif. . . . **Tom Selldorff,** S.M.'59, writes that he is currently vice president and director of operations for North and Central America for Durr Industries, a leader in specialized plants for the automotive and metal fabricating industry.

Ralph W. Sant, Jr., S.M.'36, reports, "Since my retirement in 1976, after 38 years with Gulf Oil, I have lived in Sunland, near Sequin on the beautiful Olympic Peninsula in Washington. My activities include gardening, mountain hiking, golf, fishing and community service and am currently president of the local home owners' association. I especially enjoyed living in Wassenaar, near the Hague, for the last 13 years of my service with Gulf. I regretted leaving Europe but have found many opportunities here for services to our community and happiness."

A. J. Siegel

Siegel Becomes Sloan's Acting Dean as Pounds Steps Down

Professor Abraham J. Siegel, whose special field is labor relations and collective bargaining, will assume command of the Sloan School of Management as its acting dean when Willam F. Pounds leaves his office as dean July 1. Meanwhile, the search for a permanent successor to Dean Pounds, who will return to teaching and research in the fall after 14 years as dean, will continue.

Professor Siegel has been at M.I.T. since 1954, when he came as an instructor in the Industrial Relations Section, then part of the Department of Economics. He became professor of industrial relations in 1964, when the section became part of the Sloan School. Professor Siegel's degrees are from the City College of New York, Columbia University, and the University of California at Berkeley.

XX

Nutrition and Food Sciences

The Underwood-Prescott Professorship of Nutrition and Food Science, held by **Samuel A. Goldblith,** '40, from the time of its creation until 1978, has now been assigned to Gerald N. Wogan, head of the department. Dean Robert A. Alberty of the School of Science likens Dr. Wogan's current studies of food toxicology to the work of William Underwood and Samuel C. Prescott, assuring food safety in the 1890s by solving microbiological problems in canning.

A New Look at Diets

Who should eat what?

Some new answers to this sometimes controversial question are now available from the Food and Nutrition Board of the National Academy of Sciences in the ninth edition of its *Standard Dietary Allowances*. Though the standard allowances of most nutrients remain unchanged in the new edition of this influential guideline, it includes recommendations on a number of compounds never before listed — a "signficant advance in the coverage of this standard work," write Hamish N. Munro, professor of physiological chemistry at M.I.T. who chaired the N.R.C.'s Dietary Allowances Committee responsible for the new work.

The changes:

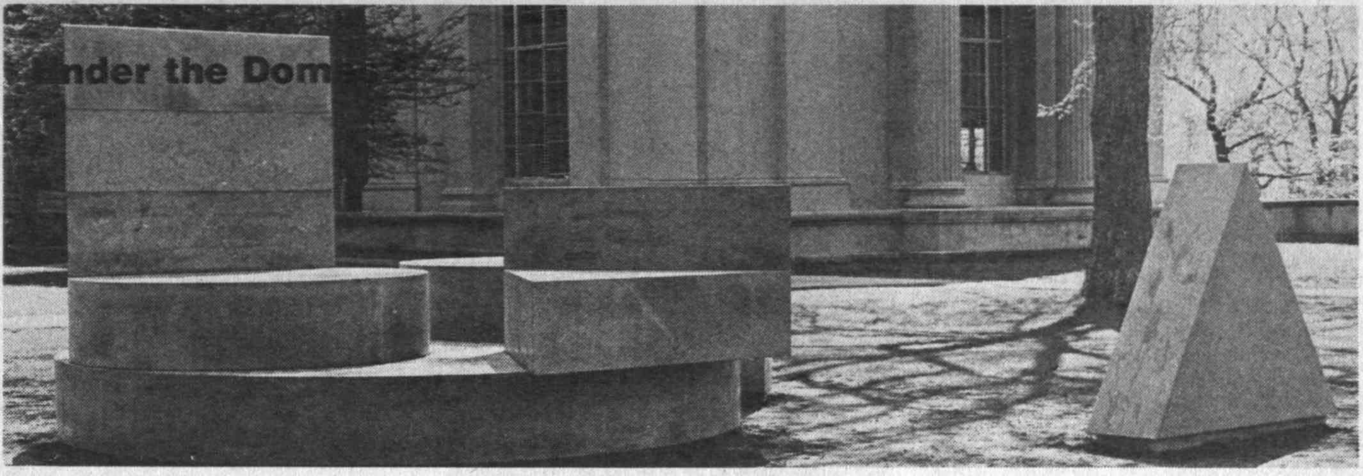
☐ Allowances are specified for six trace elements never before published: copper (2 to 3 milligrams daily), manganese (2.5 to 5 milligrams), fluorine (1.4 to 4 milligrams), chromium (0.05 to 0.2 milligrams), selenium (0.05 to 0.2 milligrams), and molybdenum (0.15 to 0.5 milligrams). ("Since many trace minerals are toxic at high levels of intake," says Professor Munro, "the upper levels given should not be habitually exceeded.")

☐ New and "much-needed" recommended daily intakes are given for sodium (1 to 3 grams), potassium (2 to 5.5 grams), and chloride (1.7 to 5 grams). These standards translate to a recommended daily intake of 3 to 8 grams of NaCl — a "rather conservative" figure which "should encourage consumers to restrict their general level of salt consumption," says Dr. Munro, "and thus reduce one of the risk factors in hypertension."

☐ Allowances for vitamin K have been added. Though this vitamin is synthesized by intestinal bacteria, the committee concluded that a standard would ensure adequate amounts.

XXII
Nuclear Engineering

Shivaji Seth, Sc.D.'70, is currently working with the General Atomic Co. in the Fuel Cycles and Systems Department, San Diego, Calif. . . . **James D. Callen,** Ph.D.'68, is professor of nuclear engineering and physics at the University of Wisconsin, Madison. . . . **Donald A. Goellner,** Ph.D.'68, has joined the firm of Dames and Moore, Washington, D.C., as a specialist in electric power systems. . . . **David L. Bodde,** S.M.'73, has been named deputy assistant for coal, nuclear, and electrical systems in the Office of Policy and Evaluation, Washington, D.C. . . . **Norman C. Rasmussen,** Ph.D.'52, head of the Department of Nuclear Engineering at M.I.T. has been elected to serve a six year term on the National Council on Radiation Protection and Measurements.



May Day Ceremony in Killian Court Heralds New Sculpture

6:30 a.m. A damp, misty May morning in Killian Court shrouds volunteer students and staff, hunched over the wet grass. They carefully place Necco wafers in a meticulous grid pattern that fills almost the entire court.

By mid-morning, pastel painted tires (yes, looking exactly like giant neccos) are in place, forming an opposing grid (see opposite page). And if one looks closely, yellow Neccos that spell 350 can be discerned, commemorating the 350th anniversary of Boston and Cambridge.

By noon the project is complete: an edible "Necco garden" (40,000 donated wafers), designed by Martha Schwartz, a landscape architect/artist, and Peter Walder, chairman of the Landscape Architecture Department of Harvard University Graduate School of Design.

The occasion is the dedication of a new sculpture to grace Killian Court. The rose-colored granite piece by Michael Heizer is entitled "Guennette."

At 2:00 the M.I.T. brass ensemble serenades curious crowds and heralds the dedication. Howard W. Johnson, Chairman of the Corporation, using a bullhorn from a perch on the new sculpture, welcomes to campus the Necco garden and sculpture. It is on extended loan to M.I.T. by the Metropolitan Museum of Art, he explains.

What is it? he asks. That is the fundamental question, and it has to be answered by each of us with "What is it *to me*," as with all important sculptures, he told onlookers. The piece will change in appearance with snow and rain. And it has the advantage, Mr. Johnson pointed out, of being a place to sit. Please sit on it if you feel the urge to, he instructed. "I think that will help you understand what it's about. It has meaning that goes beyond each of us."

Dedication day's carnival atmosphere is literally dampened by weather, but that is unnoticed. Visitors are preoccupied with the bright colors on the ground and a sky filled with soaring frisbees, some originating from the dome of Bulding 10. One passer-by stoops to pick up one, then another, wafer and pops them into his mouth. The majority of participants contentedly lick one of 750 free popsicles. That facet of May Day won unanimous approval. Reactions to the Necco garden, however, were varied:

"I don't see the point." "We should put it in front of the Necco factory." "Give us a day off from school and then let us play in the garden." "I thought the tires were real Necco wafers." "Amusing." "Playful." "Confusing." "How can this be art?" "I just love it." — *M.L.*

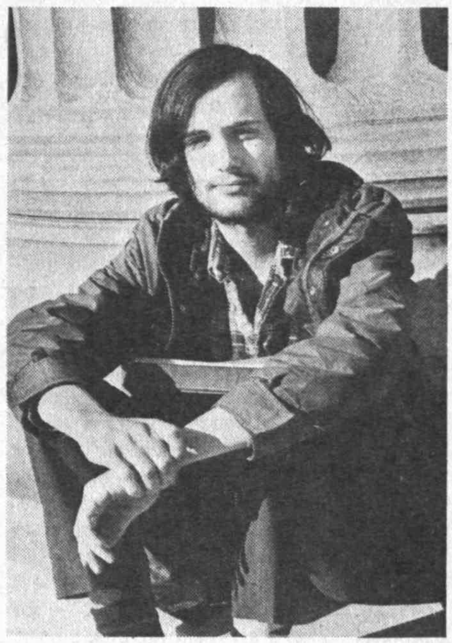
In contrast to the established older artists represented on campus such as Henry Moore and Louise Nevelson, this new sculpture is created by a young artist. Michael Heizer was born in 1944 in Berkeley, Calif., and first studied painting at the San Francisco Art Institute. His 46-ton "Guennette," slabbed from granite found in northeastern Quebec, is a circle 14 feet in diameter and 20 inches thick with ten segments of smaller circles. It now sits opposite the Henry Moore in Killian Court.

The Putnam Prize: the Best in U.S. Mathematics

"It's like the Nobel Prize in undergraduate mathematics," exulted Professor Richard P. Stanley when he learned that three M.I.T. students had swept the prestigious, national William Lowell Putnam Mathematical Competition at the end of 1979.

First place for individual went to Miller S. Puckette, '80; later, he, Daniel V. d'Eramo, '80, and Michael Roberts, '80, won the team competition. Though M.I.T. teams have scored consistently in the top five, it was the first time since 1969 that first-place honors came to the Institute's entries, and "the Math Department went wild," says Professor Stanley, the Putnam team's coach. "We had a party to celebrate."

The prizes are given on the basis of a national test — taken late last year by more than 2,000 students from 300 U.S. colleges and universities . . . a test of "ingenuity and how to put mathematical ideas together," Mr. Roberts told *The Tech*. There are 12 problems, and anyone who solves three or four of them "is in the top 10 percent in the country," Mr. Roberts said.



Miller S. Puckette, '80, was the best mathematician in the national William Lowell Putnam competition for college students in 1979, and the three-man M.I.T. team he led won first in the team contest. His win was worth $500; winning team members received $250; and the Mathematics Department from which they came received $1,500.

Sponsored Research Forecasts Rise

A revised forecast has increased M.I.T.'s expected sponsored research volume for the year 1979-80. Excluding major subcontracts, sponsored programs are likely to reach $149.8 million this year, compared with $132.7 million last year. That's an increase of 12.9 percent, compared with the earlier estimates of 11.4 percent. Lincoln Laboratory's research volume will up up 13.8 percent compared with the earlier 5.3 percent estimate.

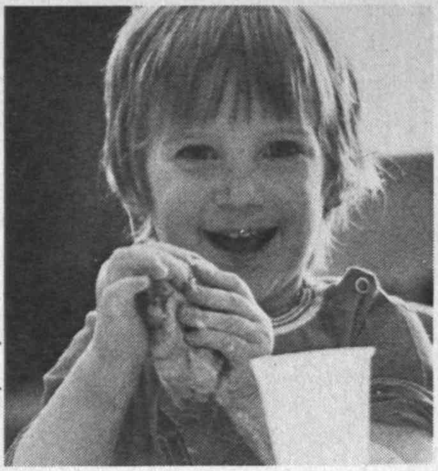
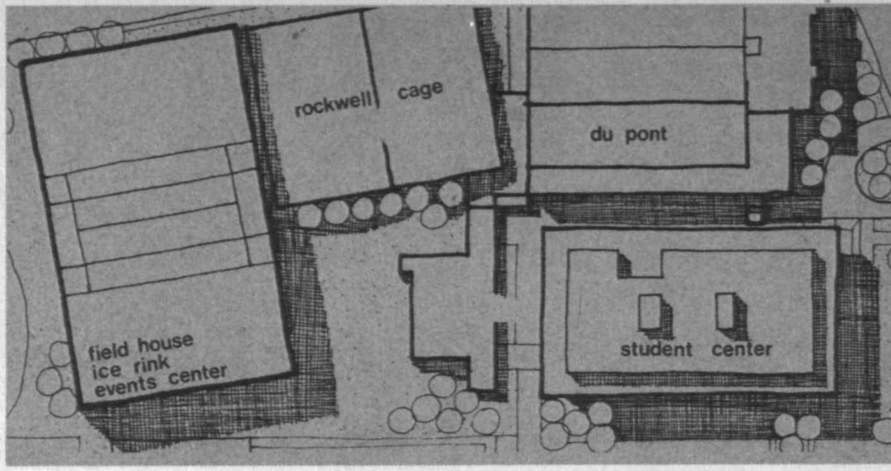


Photo: Marjorie Lyon



M.I.T. Toddlers at Work

A patient artist and a small group of young parents-turned-instructors weekly dodge airborne droplets of poster paint, brave enthusiastic movement of little hands coated with finger paint and modeling clay, and yet somehow managed to convey basic art techniques to the youngest groups of M.I.T. students — the two- to three-year-old toddlers in the Parent-Toddler Art Program at the M.I.T. Student Art Association.

The Monday afternoon classes have been taught for two semesters in the Student Center by Wendy Krum, a graduate student in the School of Architecture and Planning. They "breed creative thinking," says Malka Kutnick, director of the Student Art Association and innovator of the program. "Why do art with your child?" she asked a group of parents and children this spring. The answers flow easily: to instill the self-confidence needed to experiment, to provide an outlet for self-expression that goes beyond the verbal capability of small children, to develop dexterity and familiarity with some art media, and to provide a happy, extended period of time for parents to pay exclusive attention to their children. There are no telephones, rival siblings, or household chores to distract and interrupt.

Some observations of Ms. Kutnik:

□ Young children shouldn't be pressured to remain on a project when interest wanes.

□ Toddlers' scribbles are important to them and call for specific reinforcement — for example: "What a nice, strong, blue color!" rather than a general comment such as, "Isn't that nice!"

□ Initially expect "nonobjective art" from children of this age — that is, art that does not represent any specific object. "Grown-up artists try to regain some of these charming qualities," observes Ms. Kutnick.

□ "Don't push a child into anything he doesn't want to do."

Judging from the complete absorption of the current classes of M.I.T. toddlers (including the writer's) in their art, this last caveat is spurious. Indeed, if it were not for the lure of cookies and juice, ending the work period would be a challenge of significant magnitude. — *L.A.P.*

Special Events Center: Rescue at Hand for M.I.T. Athletics

As director of athletics at M.I.T. Ross H. (Jim) Smith understands the word flexibility. In fact, ever since he became director in 1961 he has kneaded and pulled the sports facilities at M.I.T. to best serve the community. But there are limits to even this prodigious ingenuity.

With M.I.T. recognized as having more teams competing in intercollegiate athletics than any other school, with the mandatory physical education requirement for the growing number of women students, with an ever-growing intramural program, and with a total of approximately 9,260 athletic card-holders, it is no wonder that Jim Smith ran out of options despite his reputation as a master schedule juggler.

Rescue is at hand in the present construction — after years of planning — of a new athletic center in the West Campus just beyond Rockwell Cage. It's a *big* cantilevered building — 34,000 square feet on the first floor, 54,000 square feet on the second — designed by architects Davis and Brody of New York City. The first floor will have team rooms, a public area, and indoor skating rink which replaces the outdoor rink formerly on the site. The rink area will be convertible to a 4,500-seat special events center for a variety of activities such as Technology Day, Open House, and various academic conferences.

The second floor, the field house, will house a 200-meter indoor track and a four-unit facility that can be adjusted to accommodate the needs of many different sports. This area will replace Rockwell Cage as the indoor field house for use during inclement weather; there will be built-in seating for 600 with overall capacity for 3,800. Now in the final stages of construction, the center is scheduled to open in early November, according to William Combs, '54, staff superintendent of physical plant.

Completion of the new athletic center late next fall will fulfill the first stage of a three-tiered plan which involves construction and renovation of athletic facilities throughout the campus.

Improvements in existing facilities in the West Campus area is the focus of "Phase II." That job will be started this summer with the replacement of the floor in Rockwell Cage. Other renovations still on Jim Smith's "want" list include telescopic bleachers for the du Pont Gymnasium.

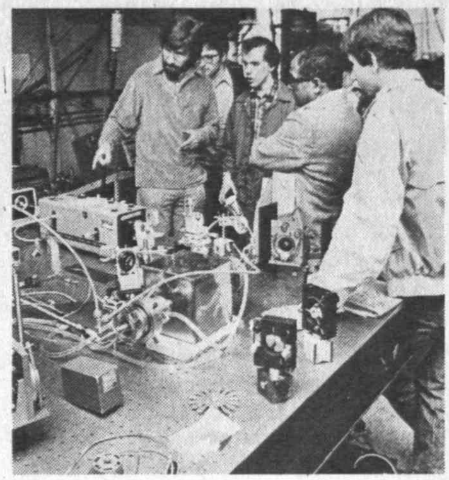
Under "Phase III" — a visionary plan first proposed by a 1975 planning team (Harry Portnoy, campus architect, says "the basic concept is still valid") — Rockwell Cage and Briggs Field House would be demolished in favor of an entirely new facility that would connect the special events/athletic center and du Pont Gymnasium and Athletic Center. This building would house a 50-meter swimming pool, gymnasium, squash courts, support facilities (lockers and team rooms), and space for other sports needs.

This finished, decentralization will become the new target. The idea here is to develop facilities throughout the campus, so that all students have recreation near at hand, says Mr. Smith. Though these visions won't be fulfilled by the time he retires this summer, Jim Smith is confident that his idea of "commitment to life outside the classroom" will be embraced beyond his tenure and be more and more fully realized in the 1980s. — *O.D.B.*

Hands Off in Cambridgeport

M.I.T. has pledged its "full support" to a Cambridge study of what to do with the Cambridgeport industrial area north of the campus. And while the study is ongoing, says Walter L. Milne, special assistant to the president for urban relations, M.I.T. "will voluntarily refrain from any real estate purchases of its own in the area."

The study was triggered when Polaroid Corp. put aside, at least for the present, its plans to build a large research and development facility in the area, where M.I.T. is a major property owner. The Institute's role has been a magnet for protest ever since its original purchase of the Simplex Wire and Cable Co. property in 1970. One local citizen group this spring charged the Institute with "an arrogant self-interest that transcends any concern for the public welfare," and the *Harvard Crimson* found a Cambridgeport resident who called M.I.T. "an octupus bent on the destruction of our neighborhood."



M.I.T. Inside Out: Open House

The public visits; the M.I.T. community turns itself inside out at Open House. From computer games to karate demonstrations; from balloons in Building 7 to baklava and popcorn in Building 10, participants could enjoy a festive atmosphere warmed by a sunny May day while exploring something of almost everything that goes on here.

A few:

A professor of applied mathematics shows computer reconstructions of galaxies interacting. He shows films of computer calculations depicting how one galaxy moves when influenced by another. The films are very speeded up — from beginning to end they would take one billion years. "Worse than watching a tree grow or a glacier move," explains the professor. "Why do galaxies travel close to each other, and what happens when they collide?" he asks. He prods the audience to grope for answers themselves.

Susan Morris, graduate student, sits on a grand piano in a small room overlooking Killian Court. Michael Loui, graduate student, assists her, now playing show tunes for those filling the room. At first glance, it looks like one is about to witness a musical. Second glance reveals a strip of paper on each chair, its ends twisted and taped together. The Möbius strip has only one side," Ms. Morris begins. As a volunteer draws a line down the middle of the circle, following her instructions, Mr. Loui accompanies him with whimsical music. Lo and behold, the demonstrator succeeds in marking both sides of the paper with one continuous line.

Now another tack. The paper strip is cut down the center, producing a surprise: one thin strip of wider diameter. Two parallel cuts dividing the paper in thirds produce two interwined loops.

"If you could climb around the Möbius strip," says Ms. Morris, "you walk around once, and you're upside down; twice, and you're right side up." In topology, it seems, nothing is intuitive.

"What is a practical use?" comes a question. "It's patented for conveyor belts," she answers.

Magic Mark, running the chemistry magic show, sends a whoosh of flames in the air from the large table cluttered with paraphernalia in front of a jammed 26-100. The throng is enthralled. He cooks an egg with liquid nitrogen, cools a flask with it to allow another egg to pop through an opening at first too small. He whips the audience into loud participation as they shout "Give me an orange!" at the exact moment that a clear liquid miraculously changes to a bright orange color. "Give me a black!" And just then, the liquid changes instantly from orange to black. He inhales helium from a large plastic bag over his head and speaks — or rather squeaks. He invites an audience member to join him in his helium atmosphere and converse. And more, and more.

"I hear and I forget. I see and I remember. I do and I understand."
– Confucius
Children have an opportunity at Open House to experience science in the laboratory rather than the classroom. Elaborate equipment loses mystery and gains accessibility when explained and touched. And questions are readily answered.

McDermott Court forms an apt stage for a karate demonstration. Families sit in a large circle, some with picnics, as a group clad in white gis and different colored belts perform a typical class, traditional individual dances based on fighting moves, and wood breaking feats.

Open house has only one frustrating aspect: too much; too short a time.

Leave 'em hungry? I was. — *M.L.*

It sounded almost like one of those deliberate "leaks" designed to test the water: Why not turn the East Campus into a graduate residential center, with Walker Memorial as its focus, and turn Ashdown House over to the displaced undergraduates – some of whom would also be accommodated in "Next House," the new building now under construction next to "New House"? The suggestion from Kenneth R. Wadleigh, '43, dean of the Graduate School, was a response to an on-campus housing shortage of increasingly serious proportions, but as the photo shows, the idea was spurned on East Campus. Undergraduates threatened to express their indignation by picketing alumni affairs, telephoning prospective students, and cancelling the proposed senior class gift. Senior House residents protested that they live there because they like it: "I like it a hell of a lot," wrote Nora Hornung, '82, to The Tech. *The bru-ha-ha ended quickly; Dean Shirley McBay called for a study of long-range housing needs; Associate Dean Robert Sherwood urged the value of "the essence and lifestyles of the dormitories"; and Dean Wadleigh agreed that his "pre-proposal" was "actively buried." (Photo: Kevin Osborn, '82, from* The Tech*)*

What the Editor Remembers

What memories will come first when the Class of 1980 thinks about M.I.T.?

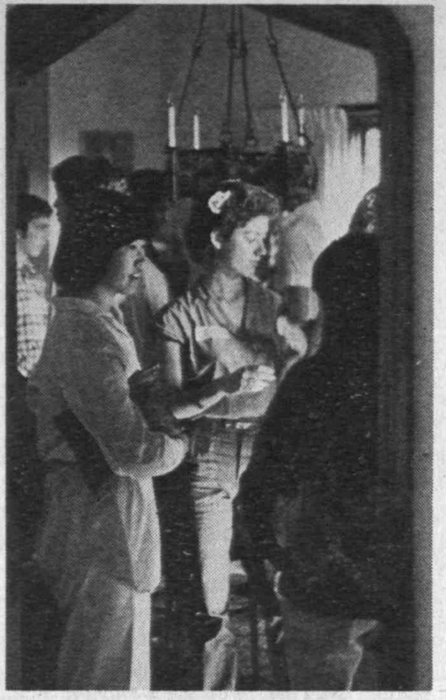
With his thesis approved and graduation only a few days away, Thomas A. Curtis, '80, turned to that question in one of his last contributions to The Tech *as its editor-in-chief. Here are four things that "stuck in my mind":*

□ *The Great Blizzard*. That was the storm that cancelled the first week of classes of the spring term two years ago. I remember walking around town during the storm and finding a nearly deserted city with absolutely no vehicular traffic. People were even walking down the middle of Massachusetts Avenue. That was the storm that caused *The Tech* to publish an issue two days late. We at *The Tech*, who pride ourselves on our record of regular publication, were heartbroken and decided to break into the paper's liquor supply to drown our sorrow. That was the only time I got really blitzed. I was sick all night, and the next day I became part of the flu epidemic which was sweeping campus. So much for the medicinal value of alcohol.

□ *The Football Club*. A football team is something I had wanted to see at M.I.T. since the day I got here. When I was sports editor of *The Tech* my sophomore year, I even wrote a column which called for the formation of a football team. So naturally I was overjoyed when the M.I.T. Football Club took the field in the fall of 1978. The Homecoming game was the highlight of that season. Having been to many M.I.T. sporting events where I was the only spectator, I was overwhelmed by the 2,000 fans who came to see the game. Everybody seemed to have fun, and not many people really cared that we lost the game. One sight I'll never forget is Leo Harten, '77, reigning as the Homecoming Queen. I wonder where they got that idea.

□ *The Consumer's Guide to M.I.T. Men*. In April of 1977, the now defunct newspaper *thursday* published a rating by two co-eds of the sexual performance of several M.I.T. men. At the time of publication, reactions ranged from laughter to those who thought it was a good hack to the indignation of those who had been given poor ratings in the article. The excitement really began the next week, however, when President Wiesner condemned the article on the front page of *Tech Talk*. Soon the wire services picked up the story and news of the Consumer's Guide appeared in newspapers across the country. At least it dispelled the myth that the only thing M.I.T. students do is study.

□ *The Paul Gray Scoop*. This last semester, I was proud to be part of *The Tech* when we announced the selection of Chancellor Paul E. Gray, '54, as the next president of M.I.T. Steven L. Solnick, '61, spent a week tracking sources before he finally had the story nailed down. Then Friday morning we had to sweat out getting the paper back from the printer. The issue finally came out an hour before the Institute's official announcement. The paper had been delayed because the printer had accidentally reversed pictures of Paul Gray and the Pope. Don't ask me how.



More than 20 of 1,799 high and secondary school students admitted to M.I.T. in the Class of 1984 attended this party at the home of Henrik H. Bull, '51, in Berkeley, Calif., on April 13. Of the 1,799 admitted, 24 percent were women, up from 20 percent in the Class of 1983, and 147 were minorities, a sharp decline from the 170 admitted a year earlier. A class of 1,050 is expected to enter the Institute in September. (Photo: Philip L. Molten, '55)

President Jerome B. Wiesner (left) and Edward E. David, Jr., Sc.D.'50, are shown signing a ten-year agreement for research on combustion science sponsored at M.I.T. by Exxon Research and Engineering Co. With M.I.T. likely to receive $7 to $8 million, the agreement is said to be one of the largest as well as longest in duration between a university and corporation. Between the two principals is P.J. Lucchesi, vice president – corporate research of Exxon Research and Engineering Co. (Photo: Calvin Campbell)

MacVicar Is Green Education Professor

The Cecil and Ida Green Professorship in Education, assigned on a rotating basis to recognize and stimulate faculty members' interest and achievement in education innovation, is now held by Professoor Margaret L. A. MacVicar, '65, director of the Undergraduate Research Opportunities Program (UROP). She succeeds in the professorship Seymour A. Papert, co-founder of the Artificial Intelligence Laboratory, who has been working on applications of computer science to education.

The professorship is one of six created at M.I.T. by Mr. and Mrs. Green; he is a member of the Class of 1923, and together they are the largest contributors to the $225 million Leadership Campaign ended this spring. Professor MacVicar has been a member of the Department of Physics faculty since 1969, two years after she received her doctorate in materials science at M.I.T.

Eugene McDermott Professorship in Psychology to Emilio Bizzi

Emilio Bizzi, a distinguished neurophysiologist, is now Eugene McDermott Professor in Brain Sciences and Human Behavior; it is a newly endowed chair made possible by the $1 million gift of the Eugene McDermott Foundation of Dallas, Tex.

It's the first endowed professorship in psychology at M.I.T., and its purpose is to ensure "the effective continuity of the late Mr. McDermott's interest in the study of human performance, constitution, and behavior." Mr. and Mrs. McDermott have been generous benefactors to the Institute.

Dr. Bizzi holds a medical degree from the University of Rome Medical School, and he came to the U.S. in the 1960s after training at the Institute of Physiology of the University of Pisa. He holds the W. Alden Spencer Award of Columbia University's College of Physicians and Surgeons for "outstanding contributions to the understanding of motor control."

A Vote of Respect from the NSF Fellows

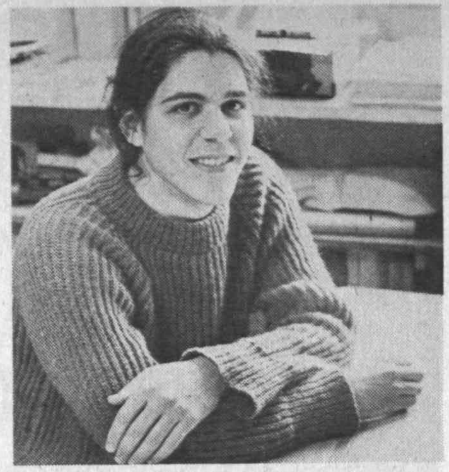
Just over 500 outstanding science and engineering students have won fellowships from the National Science Foundation for graduate study in 1980-81, and 13 percent of the winners will bring their fellowships to M.I.T. That makes M.I.T. the most popular choice nationally among recipients of NSF fellowships for 1980-81.

A Record 10-Year Research Agreement on Coal Combustion

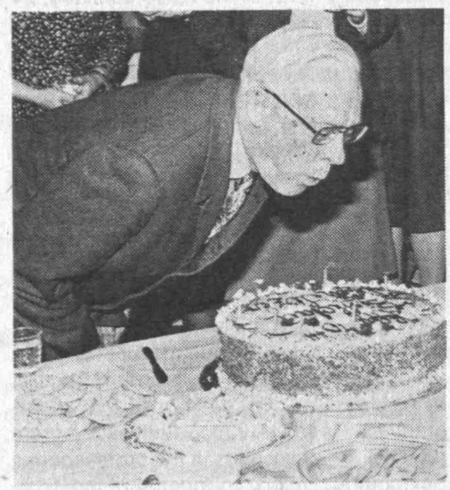
Between $7 and $8 million will come to M.I.T. for energy-related research from Exxon Research and Engineering Co. during the next decade. It will support basic scientific and engineering studies in combustion science, the specific topics to be selected by Exxon from a list of subjects proposed by M.I.T.

Edward E. David, Jr., Sc.D.'50, who is president of Exxon Research and Engineering Co., says that one of the major objectives will be to "help generate the scientific base for more efficient and more environmentally acceptable burning of high-sulfur, high-nitrogen, hydrogen-deficient fossil fuels like coal, coal liquids, shale oil, and heavy crude oil. These fuels," he said, "will account for an increasing proportion of available supplies" in the future, and Exxon seeks ways of using them which do not involve "costly and severe refining steps."

Professors John P. Longwell, Sc.D.'43, and Adel F. Sarofim, Sc.D.'62, of the Department of Chemical Engineering will be the principal investigators. On Exxon's side, the partnership will be represented by Ramon L. Espino, Sc.D.'68, director of the company's Engineering Science Laboratory, and Fred A. Horowitz, manager of the Chemical Engineering Technology Division.



Bruce Allen, '80, is one of 30 U.S. college seniors who will go to England next fall with two-year Marshall Scholarships for graduate study. He'll work at Cambridge University in applied mathematics and theoretical physics with a group he thinks includes "the best cosmologists in the world." Both his parents are alumni: Malwina G. Allen, '52, is professor of chemistry at Framingham State College, and Steven Allen, '52, is at Draper Laboratory. (Photo: Calvin Campbell)



When biochemist Irwin W. Sizer, formerly dean of the Graduate School, turned 70 this spring, his colleagues in the Department of Biology, Graduate School, and Resource Development Office threw a party in his honor. Unshaken by the surprise, Dr. Sizer extinguished every candle on the first blow. (Photo: Calvin Campbell)

Elmer C. Ingraham

Elmer C. Ingraham, '26, a member of the research staff in the Research Laboratory of Electronics from its founding in 1944 until his retirement in 1963, died on February 11 in Haverhill, Mass. He was 82.

Mr. Ingraham studied architecture at M.I.T., receiving the S.B. degree in that field in 1926.

Benjamin R. Martin, 1912-1980

Benjamin R. Martin, successful and popular coach of lacrosse and hockey at M.I.T. for 29 years before his retirement in 1974, died suddenly at his home in Seneca, S.C., on January 4; he was 68.

Mr. Martin was an all-American player at Syracuse University before he came to M.I.T. in 1945; his 1958 and 1959 teams won the national division championship, and in 1959 he was invited to coach the North team in the annual North-South lacrosse game.

As hockey coach, Mr. Martin started a round-robin hockey tournament at M.I.T. in 1962 which proved to be the forerunner of the Eastern College Athletic Association's Division II tournament; he received the 1973 Scheaffer Pen Award for his contributions to New England hockey.

James M. Faulkner, 1898-1980

Dr. James M. Faulkner, a leader in Boston academic medicine who had been M.I.T.'s medical director from 1955 to 1959, died in Boston on January 22.

Dr. Faulkner was dean of Boston University's School of Medicine for eight years before coming to M.I.T., and he continued as a physician and consultant to the M.I.T. Medical Department after retiring as its director from 1959 to 1967. Before his Boston University appointment, Dr. Faulker had served in the medical schools of Harvard and Tufts Universities.

Newton A. Teixeira, 1923-1979

Newton A. Teixeira, '44, manager of program operations in the Automated Systems Division of RCA in Burlington, Mass., died suddenly at his home in West Newton on December 31. He was 57.

Active in alumni affairs, Mr. Teixeira was co-secretary (with Mrs. Teixeira) of the Class of 1944 at the time of his death. He was also an active member of the First Unitarian Society in Newton and has written on technical engineering problems and on larger social and philosophical issues.

Elizabeth S. Smyth, 1895-1980

Elizabeth S. Smyth, librarian at M.I.T. for more than 20 years from 1920 to 1942, died on January 5 at Cape Cod Hospital in Hyannis after a long illness; she was 85.

Milton U. Clauser, 1914-1980

Milton U. Clauser, who was director of Lincoln Laboratory from 1967 to 1970 and simultaneously held a faculty post in the Department of Aeronautics and Astronautics, died in Carmel, Calif. on January 26 after a long illness. He was 66.

Dr. Clauser left M.I.T. in 1970 to become academic dean of the Naval Postgraduate School in Monterey, Calif., where he became provost. He retired in 1974.

Kurt S. Lion, 1904-1980

Kurt S. Lion, professor of applied biophysics, emeritus, who made major contributions to biological instrumentation and measurement in more than 20 years as a member of the M.I.T. faculty, died on February 27 in Watertown, Mass., after a long illness. He was 75.

Professor Lion received bachelor's and advanced degrees in engineering from the Technische Hochschule, Darmstadt, Germany, in 1928 and 1933, respectively. He came to the U.S. in 1941 to join M.I.T. as an assistant in the Department of Biology and thereafter assumed increasing responsibilities in research and teaching as a member of the faculty until his retirement in 1970. He was widely recognized for innovations in instruments for measuring and analyzing biological events and systems.

Stephen G. Simpson, 1894-1980

Stephen G. Simpson, '16, who served as assistant professor of analytical chemistry from 1933 until his retirement in 1959, died on March 23 in Wellesley, Mass. he was 85.

Professor Simpson first joined the M.I.T. teaching staff as instructor in 1919. He was made a member of the faculty following graduate study leading to master's (1931) and Ph.D. (1933) degrees, and while serving as assistant professor he wrote two widely used textbooks in analytical chemistry.

An amateur magician, Professor Simpson was a member of the Society of American Magicians.

Joseph D. Everingham, 1916-1980

Joseph D. Everingham, director of drama and professor of literature whose work over 25 years as catalyst for the M.I.T. Dramashop won high praise from students, critics, and the professional drama community, died in his sleep at his home in Cambridge on March 13. He was 63.

Professor Everingham was brought to M.I.T. in 1954 to develop a drama program utilizing the then-new facilities of Kresge Auditorium. In the intervening years his work as producer and director of the Dramashop attracted widespread admiration, and he advanced through the ranks of the faculty to professor of literature in the Department of Humanities in 1969.

A graduate of Harvard, Professor Everingham studied at the University of London in 1950-51 and then completed his master's degree at Harvard while serving as a resident tutor at Kirkland House. Though he had been in partial retirement since 1977, Professor Everingham continued to direct one major Dramashop annually.

Puzzle Corner
Allan J. Gottlieb

Allan Gottlieb is associate professor of mathematics and coordinator for computer mathematics at York College of the City University of New York; he studied mathematics at M.I.T. and Brandeis. Send problems, solutions, and comments to him at the Department of Mathematics, York College, Jamaica, N.Y., 11451.

An X-Rated Problem About Pousse-Cafes

Here are answers to several queries from readers:

Solutions to the "speed" problems appear at the end of the column in the issue in which the problems themselves appear. These problems are not to be taken too seriously, and only in exceptional circumstances do comments concerning "speed" problems appear in the "Better Late Than Never" department.

The backlog of regular problems is large, in excess of two years. For "speed" and chess problems the backlogs are a little smaller — about 18 months. But bridge problems are now in short supply — less than one year backlog.

Problems

J/J 1 Speaking of bridge problems, here is one from the late Elmer Ingraham, who writes that "I've spent too many hours that might well have been better employed to perfect this bridge problem just for your Puzzle Corner in an otherwise quite worthwhile publication":
Reputedly one of the greatest of bridge players, Mike Gottlieb, once found himself in the position of South with a four-spades contract and looking at these cards after the opponents had made no bid:

North:	*South:*
♠ 7 6 3	♠ K Q 10 4 2
♥ A 2	♥ K Q 6
♦ 8 6 5 4	♦ A 2
♣ A 7 4 3	♣ K 9 5

West opened with the ♦K. How may South best plan his play to make four spades?

J/J 2 Judith Longyear notes that integral solutions for $x^2 + y^2 = z^2$ are easy to come by. She wants you to find all integral solutions to $x^2 + y^2 = z^2 + 1$.

J/J 3 John Prussing, perhaps anticipating our increased defense research and development budget, submitted a military problem:
An army 40 miles long advances 40 miles while a messenger on horseback rides from the rear of the column to the front and back to the rear. How far has the messenger ridden?

J/J 4 The following problem, from Rudolf Marloth, should not be attempted by anyone under 21 (18 in New York):
While at a spirituous departmental (Hughes Aircraft) get-together one of my epicurean colleagues mentioned that he had started experimenting with pousse-cafés. He used a hydrometer of his own manufacture to determine the order of the layers. My reaction was that only an ordering of specific gravities was needed, not the actual values, so I would have compared equal volumes on a balance. The question is, How many one-on-one comparisons would be needed to order six (never mind N, I'm an engineer) liqueurs if no two have the same specific gravity? Furthermore, could one do better by comparing them in groups?

J/J 5 Our final regular problem was shown to me by John Febbo during a wedding reception a few years ago; it is known as the Smith-Jones-Robinson classic, a "masterpiece of its kind," say the instructions. "It is reported that in one group of 240 people trying it, only six came up with the solution. But there is no 'catch' in it, and the answer has been worked out by many people in five to ten minutes. *Every fact* is important and must be considered." Here it is:
On a train, Smith, Robinson, and Jones are the fireman, brakeman, and engineer, but *not* respectively. Also aboard the train are three businessmen who have the same names — a Mr. Smith, a Mr. Robinson, and a Mr. Jones.
1. Mr. Robinson lives in Detroit.
2. The brakeman lives exactly half way between Chicago and Detroit.
3. Mr. Jones earns exactly $20,000 per year.
4. The brakeman's nearest neighbor, one of the passengers, earns exactly three times as much as the brakeman.
5. Smith beats the fireman at billiards.
6. The passenger whose name is the same as the brakeman's lives in Chicago.
Who is the engineer?

Speed Department

J/J SD 1 A problem from Smith Turner: One boat starts from the east side of a lake and heads west at a constant speed. At the same time another boat starts from the west side and heads east at a constant speed (not necessarily the same as the first boat). When each boat reaches the opposite side it turns around and returns. The boats meet, for the first time, 300 feet from the east side and, for the second time, 400 feet from the west side. How wide is the lake?

J/J SD 2 Ted Mita wants to know: If you are facing a person who is pressing the backspace key on a manual typewriter, in which direction is the carriage moving?

Solutions

FEB 1 White sets up chess pieces in standard form to start a game and has first move. Black sets his king in normal position; he may set what other pieces he uses on any unoccupied squares. For Black to have a forced win,
1. What is the least number of pieces that Black needs, what are they, and where are they placed?
2. If Black is restricted to pawns only, what is the least number needed, and where placed?

For part 1, Edward Friedman notes that if Black has knights on his Q6 and KB6, White is "mated." I use quotes as this position cannot occur in a game, since White must have been in check before Black's last move. Requiring a legal position leads to the following solution from Matthew Chen, James Shearer, Winthrop Leeds and Gardner Perry: N on K5, B on KR5, and Q on KB5. Part 2 is harder. Several readers had solutions with five or six pawns but each had a flaw, usually having White starting by QP × P or KP × P. Matthew Chen, however, has a solution using *nine* pawns placed on QB6, Q6, K6, KB6, KN6, K5, KB5, KN5, KR5. Of course this isn't a legal position. Thus the problem is still open unless someone can show that no solution with eight pawns is possible.

FEB 2 A rope on the roof of a carport, with part hanging over the edge, begins to creep, gains speed, and finally falls entirely to the ground. Suppose the roof was horizontal and perfectly smooth, the rope a slippery, flexible, homogeneous line mass five meters long overhanging one centimeter, and the edge mechanically equivalent to a frictionless sheave of infinitesimal radius, how long would it take the rope to slither off the roof?

The following solution is from Irving Hopkins:
We let:
L = length of rope = 500 cm.
x = length of rope hanging down, in centimeters; x_0 = 1 cm.
g = 980 cm./sec.^{2}
t = time, in seconds, after release of the rope.
m = mass of the rope, in g./cm.
The potential energy of rope lost by the 1 centimeter of stationary rope is the weight of it, times the lowering of the center of gravity:
$(m \cdot g \cdot x_0)(x_0/2) = m \cdot g \cdot x_0^2/2$. If the length x is hanging down, the potential energy converted to kinetic energy is
$(mg)(x^2/2 - x_0^2/2)$, with the resulting kinetic energy being $mL(dx/dt)^2/2$. Equating these two and simplifying, we have $g(x^2 - x_0^2) = L(dx/dt)^2$, or
$dx/dt = \sqrt{g/L}\,\sqrt{x^2 - x_0^2}$
Rearranging this for integration, we have
$$\int_{x_0}^{L} dx/(x^2 - x_0^2)^{1/2} = (g/L)^{1/2}\int_0^t dt, \text{ from which}$$
$\ln([L + (L^2 - x_0^2)]/x_0) = (g/L)^{1/2}t$, which gives $t = 4.934$ seconds.

Also solved by Peter Wender, Edward Nadler, R. Alward, Everett Leroy, Victor Newton, Winslow Hartford, D. Gupta, Timothy Malony, Anonymous,

Michael Jung, Harry Zaremba, John Prussing, Chuck Whitney, Edward Friedman, James Shearer, Winthrop Leeds, Gerald Blum, Gardner Perry, and the proposer, the late R. Robinson Rowe.

FEB 3 In lieu of a conventional key lock, each room in my hotel was equipped with a cipher lock that responded only to the four-digit code selected by the guest when registering. In the course of playing with the lock, one guest noted that the lock would open (indicated by a green LED) whenever the correct code was the last four digits of any sequence. In other words, any amount of garbage could be keyed in; if the last four digits matched, the bolt was energized. It occurred to me that the enterprising burglar would need to try many fewer than the 10,000 possible combinations if he could define a digit stream with the characteristic that each new digit entered resulted in a new four-digit sequence. The minimum number of entries must be 1,003 — four digits to enter the first number, with each of the subsequent 999 resulting in a new sequence. What is the minimum number of keystrokes required?

This problem is part of the computer sciences literature. A summary of an effective algorithm was submitted by Harold Fredricksen and James Maiorana and is reprinted below. Anthony Ralston, a past president of the Association for Computing Machinery, Donald Savage, and J. Swenson also submitted solutions. Timothy Maloney and Gerald Blum noted that 10,003 digits are required.

The solution is a sequence of decimal digits of length 10,003 containing each different length four sequence of decimal digits. In fact it is no restriction to ask that the last three digits of the sequence be identical to the first three digits and then a cycle of length 10,000 is sought. More generally, we require a cycle of length k^n containing every different n-long string of digits chosen from an alphabet of k letters. This problem is known as the Good-deBruijn sequence problem. The cycle asked for in the problem is too long to be presented here, but a smaller example and an exposition of the generating algorithm can be given so that the general n, k cycle can be obtained. For $n = 2$, $k = 4$ we have the cycle 3323130221201100 of length $4^2 = 16$. We obtain the sequence from the algorithm given below. First we define a subtraction operator θ. θ operates on strings of digits of length n to form similar strings, thusly

$a_1a_2 \ldots a_n\theta = (a_1 \ldots a_{j-1}a_j - 1)^q\, a_1 \ldots a_s,$

where $a_j > a_{j+1} = \ldots = a_n = 0$ and $0 \leq s < j$. By $(a_1 \ldots a_{j-1}a_j - 1)^q$ we mean that the string $a_1 \ldots a_{j-1}a_j - 1$ is repeated q times and necessarily $n = qj + s$. If $s = 0$, for $a_1 \ldots a_s$ we write the empty string.

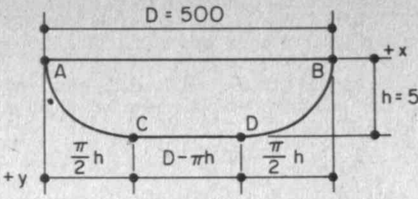
Algorithm (n,k)

1. Initial string is $m = (k - 1)^n$, output $k - 1$.
2. Repeat $m \leftarrow m\theta$ until $s = 0$.
3. Write m as $(a_1 \ldots a_l)^{n/l}$ where l is as small as possible. Output $a_1 \ldots a_l$.
4. If $m = (0)^n$, go to 2; otherwise output $(k - 1)^{n-1}$ and stop.

This last output is not necessary for the length n^k cycle but is necessary for the sequence description of the problem. We use the operator θ instead of the simple arithmetic operation -1 with a test if the resulting n-tuple is the largest element of its equivalence class under cyclic rotation because θ obviously makes the algorithm go faster. A more careful exposition of the algorithm with a proof that it works as well as a guide to related literature can be found in the paper by H. Fredricksen and J. Maiorana in *Discrete Mathematics,* Vol. 23 (1978), pp. 207-210.

FEB 4 It is known that the fastest way to get an object from point a to point b in a uniform gravity field is a cycloid. If a and b are 500 miles apart, the maximum depth of the cycloid would be 159 miles. What is the fastest curve if there is a more severe depth limitation — e.g., 50 miles?

Several readers proposed using part of one cycloid, but I agree with Harry Zaremba *et. al.* that two "half cycloids" connected by a straight line is faster. Mr. Zaremba's solution:



Ignoring friction and air resistance, the fastest path or brachistochrone will be shown in the figure — composed of a half cycloid AC and DE at each end interconnected by a straight tangent line CD. The time for an object to fall a distance h from A to C will be:

$$t = 1/\sqrt{2g} \int_0^{\pi h/2} y^{-\frac{1}{2}}(1 + \dot{y}^2)^{\frac{1}{2}}dx, \tag{1}$$

in which y is the ordinate to any point, $\dot{y}$ is the slope of the cycloid at the point, and g is the acceleration of gravity (32.2 ft./sec.^{2}). Using the calculus of variations, the parametric equations for the path AC are

$x = h/2 \cdot (\pi - \theta - \sin 2\theta)$

$y = h/2 \cdot (1 + \cos 2\theta)$,

where h is the depth and the parameter θ is the angle between a tangent to the curve and the x-axis. When $\theta = 0$, the horizontal distance travelled from A to C is $x = \pi h/2$. The maximum speed along the line CD will be equal to $v = \sqrt{2gh}$, and it is identical to the velocity attained by an object falling freely through a vertical distance h. This velocity, together with the cycloidal ends, assures an optimum speed and minimum time. Utilizing the parametric equations, integration of equation (1) yields the following time to travel from A to C: $t = \pi\sqrt{h/2g}$. The total time to traverse the path is given by

$T = 2t + (D - \pi h)/v = 2\pi\sqrt{h/2g} + (D - \pi h)/(2gh)^{\frac{1}{2}}$.

For $h = 50$ miles, $T = 841.41$ seconds or 14.02 minutes.

Also solved by John Prussing (who has written a paper on this subject in the *American Journal of Physics* — Vol. 44, No. 3, p. 304), D. Gupta, R. Alward, Winslow Hartford, and the proposer, David Gluss.

FEB 5 Five people had consecutive appointments with an income tax expert to help them fill out their 1040 forms and schedules. The electrical engineer had income from a savings account. The man who had a profit trading commodities was taking educational expenses as a deduction. When the man who contributed to a charity was leaving he met the taxpayer with dividend income. The biochemist is deducting interest on a mortgage. The computer programmer uses an SC-40 calculator. The man with three dependents is claiming storm damage as a deduction. The man with the charitable deduction followed the physicist. The man with five dependents exchanged amenities with the owner of the SR-50. When he looked at the tax expert's calendar, the man with the MX-140 noticed his name was next to that of the man with three dependents. The man with seven dependents sold some real estate for profit. The mathematician has six dependents. The income tax expert still had more than one scheduled appointment after he met the man with dividend income. Each man had a profession, owned a calculator, had a deductible expense, had some number of dependents, and had a second source of income. Who won money in a contest? Who owned an HP-45 calculator?

There seems to be some trouble with this problem as only four calculators were mentioned for five people. I looked at the proposer's *solution* and a C 1400 calculator is included so perhaps part of the problem was inadvertently omitted. Until we hear from Mr. Butler, I offer Roy Blackmer's solution as best fitting the spirit of the problem:

Part of the warm-up for filling out federal tax forms is making educated guesses about items for which there is inadequate documentation. By using my imagination a bit I arrived at the following answers:

The physicist won money in a contest. Incidentally, he has only one dependent (himself) and takes a deduction for alimony. The biochemist

owns an HP-45. The mathematician has a TI-12 but does most of his calculating with a PDP-1170. The facts about the five people are:

1. *Physicist*
   SR 50
   Deduction for alimony
   One dependent
   Won money in contest
2. *Electrical engineer*
   MX 140
   Charitable contribution
   Five dependents
   Income from savings
3. Computer programmer
   SC 40
   Storm damage
   Three dependents
   Dividend income
4. Mathematician
   TI 12
   Educational deduction
   Six dependents
   Commodity profit
5. Biochemist
   HP-45
   Mortgage deduction
   Seven dependents
   Real estate income

While the above may not qualify as a unique solution, it probably fits the facts more closely than many tax returns.

Responses also received from Winslow Hartford, Yale Zussman, Avi Ornstein, Amnon Stchin, Matthew Fountain, Charles Swift, Matthew Chen, Gardner Perry, Gerald Blum, and the proposer, William Butler.

Better Late Than Never

J/J 1 Mike Bercher and Smith Turner have responded.
A/S 4 Robert Prince and a hard working TI-57 (35 days of computation) have responded.
OCT 2 Irving Hopkins and John Longhaar note that the final formula may be more simply expressed as $x = \cosh(y)$.
OCT 3 John Longhaar has responded, and the following letter (plus a long print-out) was received from Walter Nissen:
This is a curious problem. I have explored many of its nooks and crannies, but I have not found a simple solution. Let

$$N_k = \sum_{i=1}^{k} A_i,\ A_i < A_{i+1}.$$

I found a plausible technique while considering $k = 3$. It was satisfactory for solving that case ($6 + 19 + 30 = 55$). It also quickly lucks into $k = 4$, where $1 + 22 + 41 + 58 = 122$. Thereafter, I had the patience to write a computer program to do the trial-and-error portion but not to do it by hand. Let $(S_i)^2 = N - A_i$. Suppose that an N not known to be the minimal N_k is found to satisfy all the other requirements, then if $A_i < 1 + 2S_k$, N_k will be associated with the same S_k. This makes the algorithm much more efficient. Results:

$$N_7 = 2210 = 1 + 94 + 185 + 274 + 361 + 529 + 766$$
$$N_8 = 3156 = 20 + 131 + 240 + 347 + 452 + 555 + 656 + 755$$
$$N_9 = 4908 = 8 + 147 + 284 + 419 + 552 + 683 + 812 + 939 + 1064$$
$$N_{10} = 8656 = 7 + 192 + 375 + 556 + 735 + 912 + 1087 + 1260 + 1600 + 1932$$

Note that for $k \equiv 0, 2 \pmod 6$, $S_i = (k-1)^2 + i - 1$ gives rise to a (possibly non-minimal) solution. It is clear that $(x-2)^2 + (x-1)^2 + (x+3)^2 = (x-3)^2 + (x+1)^2 + (x+2)^2$. There are numerous similar relations. With this in mind, perhaps Mr. Duffy would like to give the three partitions of $N_{60} = 12531610$ which satisfy the problem conditions.

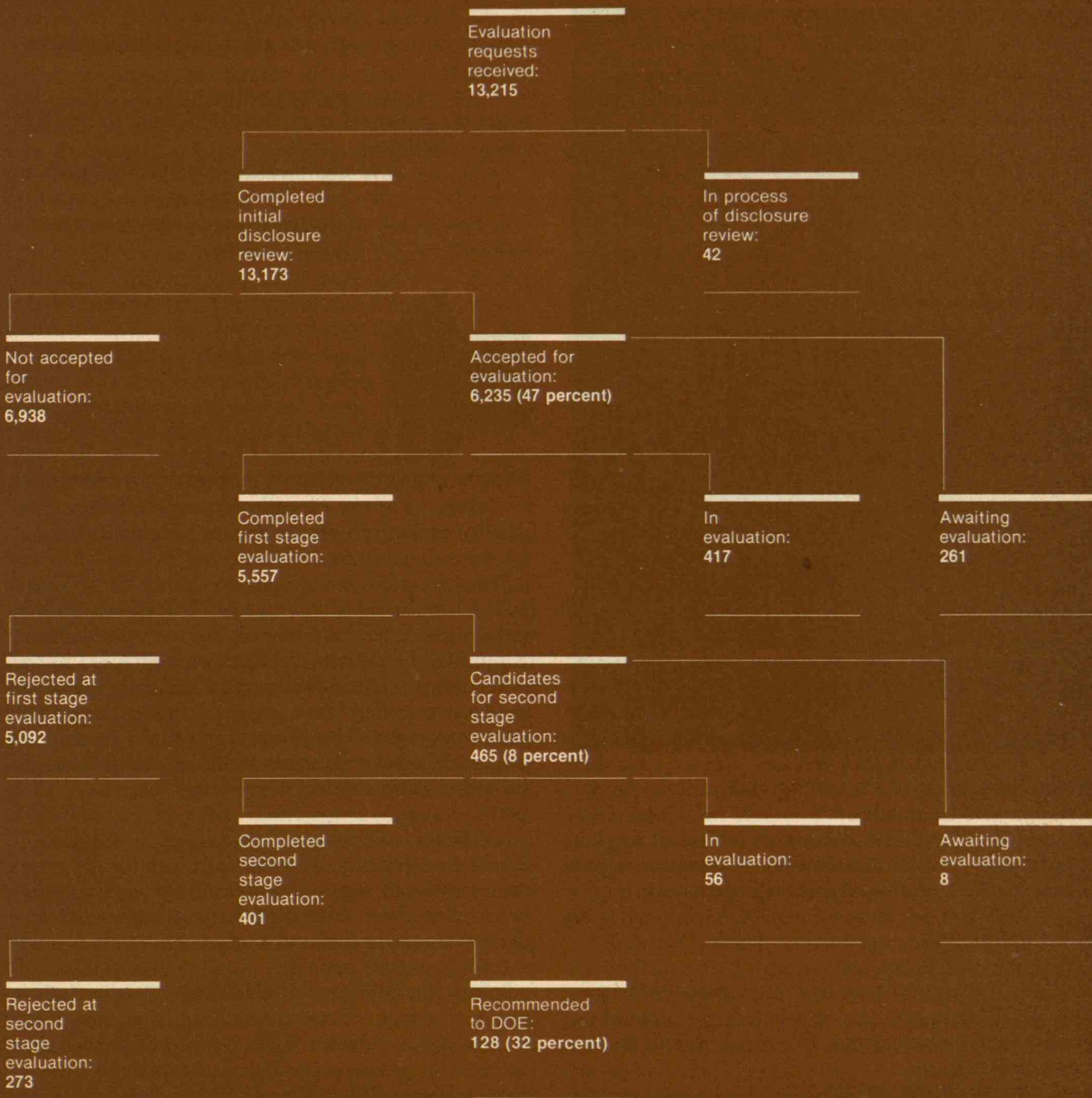
Before he mailed that letter, Walter Nissen received the February issue, and he added a postscript pointing out that the solution published there was in error and that he wished his had been mailed in a timely fashion. Then he adds:
I am still quite unsatisfied with my understanding of how to proceed against this problem, but apparently I have picked up a trick or two not recognized by the other solvers. Incidently, my program, which is written in rather inefficient interpretive BASIC, computes cases $k = 7, 8, 9$, and 10 in about six seconds on my Prime 400 minicomputer, although running $k = 2$ thru 210 took many, many hours ($k = 60$ took 6 minutes 44 seconds). Perhaps my use of Algorithm 154 of the Collected Algorithms of the ACM to generate combinations in canonical order and the minimality theorem stated above are responsible for the contrast in efficiency between my program and Al Weiss'. Of course, I am making no claims concerning development time.

NOV 1 Mike Bercher has responded
NOV 2 Mike Bercher has responded
NOV 5 Mike Bercher has responded
D/J 1 Alan LaVergre and Mike Bercher have responded.
D/J 3 Alan Lavergne has responded.
D/J 4 John Longhaar, Alan Lavergne, and A. Alward have responded.
D/J 5 Alan Lavergne and Edward Nadler have responded.

Proposers' Solutions to Speed Problems

SD 1 By the first meeting the boats have combined to make one crossing. By the second meeting, three crossings. Thus the width plus 400 feet that one boat travelled by the second meeting is three times the 300 feet it had gone by the first meeting. So the width is 500 feet.
SD 2 To the left.

The results of the National Bureau of Standards' (NBS) evaluation of 13,215 disclosures received from inventors through the end of 1979. DOE has found that about 1.3 percent of the disclosures can be expected to win funding: 47 percent accepted for evaluation × 8 percent accepted for "second-stage" evaluation × 32 percent recommended by NBS for DOE support.



A classification of 41 inventions accepted for DOE support prior to 1979 relating the number of grants to purpose of support and perceived technological risk. Note that reasonable balance was achieved for these two variables in the spectrum of awards.

Purpose of support	Technological risk	Number of positive award decisions
Basic research	High	2
Research and development planning		1
Applied research	Medium	12
Prototyping and/or testing		17
Estimation of performance and/or cost	Low	1
Improvement of an already-marketed invention	Proven	2
Development of a business and/or financial plan		1
Assistance with marketing and/or development of market information		5
Total positive decisions as of December 31, 1978		41

availability, or the probability that return on investment will be much better in the near future because of decreased unit costs with increased market penetration. In addition, careful assessment of potential markets of an innovation is necessary.

Five Case Studies

We have studied in detail five innovations that have won DOE support and estimated the economic viability and energy impact of four. In each case we have reviewed:

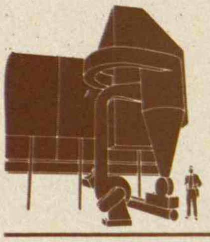
☐ Estimates of the invention's possible energy impact.

☐ Assessments of the invention's business potential on the basis of energy-savings potential, estimated manufacturing costs, and the nature of the particular markets.

☐ Barriers to commercialization and the innovator's plans for transferring the new technology into the economy.

☐ The role and significance of DOE support in stimulating technology development and transfer.

A description of the five typical innovations and a summary of our findings follow.



Modification of the Flexaflo Dryer (DOE No. 56); Quality Industries, Inc. (licensee), Thibodaux, La.

This invention is a system for drying "wet" crop-processing wastes for use as fuels. Stack gases from a natural-gas-fired boiler are used as a source of heat to remove the moisture. The dried fuel is fed to the boiler, supplementing the natural gas. Formerly, wet fuel was supplied directly to the boiler, requiring much more gas. The initial application of this invention has been in sugar mills, which commonly use sugar cane residue, known as "bagasse," as a fuel.

In theory, the bagasse output of a sugar mill (about one-quarter ton wet waste per ton of processed cane) can supply all the mill's energy requirements. But the combustion of wet bagasse is less efficient than dry fuel and leads to boiler efficiencies of only about 50 percent.

Before the DOE award was made, Quality Industries had designed, constructed, and installed three of these bagasse dryers. They performed so well that the need for gas was eliminated under steady operating conditions. Prior to the development of this form of dryer, typical Louisiana sugar mills required about 1,000 cubic feet of natural gas (producing

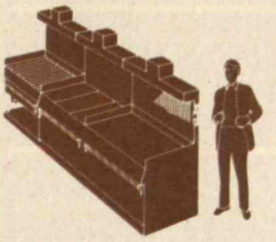
about 1 million Btu's) to process 1 ton of sugar cane. This performance was far superior to that of two alternative drying methods: air-drying bagasse in storage (not very practical for large sugar mills that typically have capacities from 200,000 to 600,000 tons of cane per season), and preheating the air used for combustion with heat-recovery equipment energized by the stack gases.

Despite the promise of remarkable energy savings, Quality Industries had to overcome two major hurdles that required substantial development capital: the development and testing of a seal for the top of the dryer to prevent air from being carried into the system with the bagasse; and the development and testing of filter screen and scrubber systems to remove particulates (bagacillio) from the stack emissions. DOE granted $111,220 to the firm to overcome these problems, which also used about $500,000 of its own funds for the original development and these improvements.

The DOE award, which came in September 1978, enabled Quality Industries to improve the drying system at one sugar refinery so that operating results for half the 1978-79 season could be obtained. The modified installation proved to have even higher drying capacity than originally estimated, and in the opinion of Quality Industries it is a proven success. Unfortunately, relatively high U.S. labor costs have led to increased imports of low-cost foreign sugar. The potential market for these dryers in U.S. sugar mills (and other appropriate industries) is still sizeable — as are the potential energy savings. About 20 million tons of sugar cane are processed annually in the U.S.— about 10 million tons in Hawaii and 5 million tons each in Louisiana and Florida. However, the potential market in the Louisiana area for dryers has shrunk from over 35 four years ago to about 10 today.

The total supplemental energy that could be saved, based on 1 million Btu's per ton of sugar cane processed, is thus about 20 trillion Btu's per year — about 0.03 percent of total U.S. energy consumption. This small energy impact could be greater if the dryer were applied to other industries such as pulp and paper, municipal refuse, and the preparation of wood for firing utility boilers, as is contemplated in some New England states.

DOE funding was crucial to making the improvements to complete the development of this dryer — without this funding, the project would have been terminated. Its application to other industries needs to be explored because of the depressed state of the U.S. sugar industry.

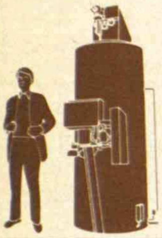


Waste heat utilization for commercial cooking equipment (DOE No. 27); Robert J. Jones, Hydrocoil Manufacturing Co., Los Alamitos, Calif.

The Hydrocoil is a device that recovers low-grade heat from the flue gases of natural-gas-fired commercial cooking equipment. Water circulated through finned coils of tubing captures and transfers the heat to domestic hot water or ventilation air. Located within the flue, the heat recovery coil cannot be fouled with hot grease and so can be used only with cooking units such as ranges with griddle tops, hot tops, or deep-fat fryers. The entire system is fabricated from standard hardware and equipment using skills similar to those needed for plumbing and the installation of commercial cooking equipment. There are no significant technological problems to be solved in the development of the product.

Support from the Department of Energy enabled the inventor to fabricate one prototype device for preheating water and one for preheating air. These are being evaluated by Calspan Corp. and the American Gas Association. Independently, the inventor has installed a Hydrocoil in a California restaurant with instrumentation to measure in-service performance. The resulting data will be very valuable in understanding the impact of this invention.

With continuing increases in energy costs, the Hydrocoil could become a good energy conservation investment for many businesses around the country. With 100,000 installations each recovering 125,000 Btu's per hour for 18 hours per day, 48 billion cubic feet of natural gas could be saved annually. At 1 million Btu's per 1,000 cubic feet, the savings would amount to a significant 0.06 percent of U.S. energy use.



Direct-flame-contact high-efficiency water heater (DOE No. 53); Harry E. Wood, New Orleans, La.

Mr. Wood's water heater design is about one-third more efficient than conventional gas-fired water heaters of similar output; it heats water by bringing the gas flame and combustion products into direct contact with the water. The combustion rate and the water flow rate are adjusted so that the water reaches the desired temperature in a single pass through the unit. Heated water is stored in a reservoir at the bottom of the tank assembly. A forced draft mixes air and gas prior to combustion and drives the flame through the heat-transfer region. Stack temperatures are very near the temperature of the inlet water — evidence that the efficiency of this heater is substantially greater than that of conventional gas-fired water heaters, whose stack gas temperatures are well above the boiling point of water at atmospheric pressure.

Conventional water heaters also lack the ability of Mr. Wood's heater to recover the latent heat of vaporization contained in the water vapor formed during the burning process.

Mr. Wood built a small water heater and tested it in his own home prior to receiving a DOE grant in May 1978. The grant enabled him to build a commercial-size unit capable of heating 50 gallons of water per minute (equivalent to 2.4 million Btu's per hour) and to install it in a 210-unit apartment complex. The performance of this heater has been so good that Mr. Wood has obtained orders for eight commercial-size water heaters (with an output ranging from 2 to 23 million Btu's per hour). He has received additional orders to make modified units to recover waste heat from boiler stacks.

Mr. Wood's water heater design has stabilized, and he has obtained safety approval from the Factory Mutual Engineering Research Corp. for the components and statements from an independent testing laboratory and the Louisiana Board of Health that the water from it is fit for human consumption. Should similar approval not be won in other states, there is still considerable market potential for this type of water heater in the food-processing and laundry industries and as a replacement for conventional boilers in hot-water space-heating systems. Mr. Wood is considering joint-venture possibilities with larger organizations to supply such potentially large markets. He does not consider the single-residence home market attractive because the heater controls are quite expensive, putting his design at a disadvantage against small, conventional heaters.

The economic prospects for the direct-contact heater depend strongly on whether potential buyers can be persuaded that it will yield a favorable return on investment. Over a 10-year life, the heater would produce a rate of return of 18.8 percent on the extra capital needed to install it (instead of a conventional gas-fired unit), producing a payback period of about 5.3 years (without tax incentives and using a 1978 gas rate of $2 per million cubic feet; this rate is more nearly $3 per million cubic feet as of 1980). This estimate, adjusted for the rapidly increasing gas rates, suggests that the direct-contact heater may be competitive chiefly in regions with higher-than-average energy costs. New England would seem to be an especially good potential market area.

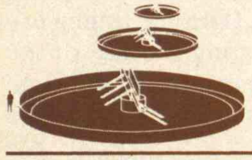
The somewhat greater complexity of the control system could be a minor barrier to commercializa-

Return-on-investment estimate for the bagasse dryer, based on a 200,000-ton-per-season plant, the minimum size for economical operation. Such a plant in Louisiana or Florida would be onstream 1,500 to 1,800 hours per season. A Flexaflo dryer for such a plant would cost about $300,000, plus $50,000 for installation. Straightline depreciation is used and a 10-year life is assumed. The effects of any available tax credits are not considered.

Annual energy saving		$400,000
Annual expense		58,000
Labor	$10,000	
Repairs & maintenance	6,000	
Taxes & insurance	7,000	
Depreciation	35,000	
Annual expense saving		$342,000
Income taxes at a 50-percent rate		(171,000)
Change in net profit after taxes		$171,000
Average annual capital investment		$175,000
Annual return on average investment		98 percent

tion. Some special training will be needed by service people, although the system is assembled from standard components.

Widespread use of direct-contact water-heating technology could save considerable energy. The energy consumed by commercial-size gas-fired water heaters is about 2.3 percent of total U.S. energy consumption. This estimate is based on gas-fired water heaters having 80 percent penetration of the commercial market, 50 percent of the apartment market, and industrial use comparable with commercial use. If the quality of the hot water produced by direct-contact water heaters is accepted generally as potable, and all these users convert to direct-contact water heaters, savings could come to an impressive 0.6 percent of total U.S. energy consumption.



Wastewater aeration power control device (DOE No. 47); Robert M. Arthur, Arthur Technology, Fond du Lac, Wis.

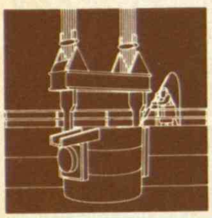
This invention can help save energy in wastewater treatment plants. It senses and measures the biological oxygen demand created by microorganisms that break down activated sludge. Its use would help make possible a reduction in the excess air needed in the treatment plants. Currently, the compressors that force air into treatment tanks run constantly, even when oxygen is not needed; the energy savings would result from running them only when necessary. Mr. Arthur developed the basic concept for his sensor several years ago and has been selling versions suitable for laboratory use. The sensor isolates and aerates a sample of wastewater and then measures the vacuum created as the microorganisms consume the limited oxygen. It also scrubs out the carbon dioxide produced by the microorganisms to prevent their premature demise.

The DOE grant enabled the inventor to develop a cheaper, less-sophisticated model of the sensor that would be suitable for large-scale use in wastewater treatment plants. The firm is now testing and calibrating the first such instrument in a wastewater environment and plans to build, install, and test five additional instruments. Test results will be used to fine-tune the design, after which Mr. Arthur envisions marketing through his company's existing channels.

A comparatively brief payback period, based on energy savings of approximately 25 percent of the electrical power now being used for aeration, enhances the promise of economic viability for this product in both small and large wastewater plants, including those used industrially. Very conservative estimates indicate that the device will pay for itself in only one to two years when used in activated sludge treatment plants that process less than 5 million gallons of wastewater per day. Use by plants with larger treatment capacity could result in an even brighter economic picture. Of course, these estimates assume the concomitant use of compressors

suitable for modulated control.

Projected national energy savings are equivalent to 2.2 million barrels of oil per year, based on combined 1977 energy consumption figures for all U.S. municipal activated sludge wastewater treatment plants. Projecting future growth, including industrial wastewater treatment, use of this innovation could save about 22 million barrels of oil per year by 1990.



Conservation of electrical power through the analysis of low-carbon aluminum steels using oxygen sensors and iron aluminum alloy (DOE No. 18); George R. Fitterer, Fitterer Engineering Associates, Inc., Oakmont, Pa.

The liquid steel produced in a basic oxygen furnace contains a considerable quantity of oxygen that must be removed before solidification. One method of doing this is the addition of aluminum to the melt, where it bonds chemically with the dissolved oxygen. About 20 percent of the steel made in the U.S. is treated in this fashion. This DOE-funded project is a patented oxygen sensor called an "O-Probe," which may help to save energy by providing more precise control of aluminum "trim."

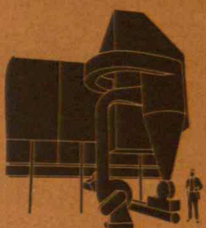
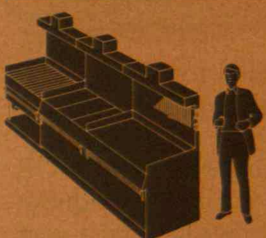
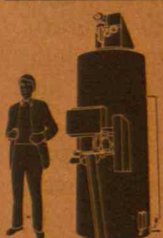
The quality of low-carbon, aluminum-killed (LCAK) steel in each individual melt depends on adding just the right amount of oxygen-absorbing aluminum. Operators now make this judgment by observing subjectively certain characteristics of the melt. Though samples of steel are sent to the laboratory for analysis, test results do not come in time to be used in a determination of how much aluminum should be added. If a particular melt of steel contains too much aluminum or not enough, then it is considered an off-grade melt and either sold at discount as lower-grade steel or scrapped. The imprecision of this technique entails losses of the energy required to melt the steel and produce the aluminum. (About 3.5 times as much energy is needed to produce a pound of aluminum as to produce a pound of steel.)

In principle, the O-Probe, a zirconium sensor that quickly measures the oxygen content of steel, should provide the information needed in time to optimize the addition of aluminum. But the aluminum-oxygen equilibrium in steel is not well understood, and control is difficult because of aluminum's low density and its high reactivity in liquid steel. Aluminum reacts vigorously with the air and the slag on top of the melt as well as with the oxygen dissolved in it. These side reactions greatly complicate the prediction of the final aluminum content of LCAK steel. As a result, the use of the O-Probe has not been as rewarding as hoped. (Fitterer Engineering Associates is currently evaluating the use of an aluminum alloy that is denser than pure aluminum and may reduce the side reactions of aluminum with air and slag.)

DOE continues to support work on the O-Probe in the hope that its use can reduce both scrappage and intrinsic energy loss. Fitterer Engineering Associates, in cooperation with McLouth Steel Corp. of Trenton, Mich., has used O-Probes at various stages in the steel-making process to obtain data on the reactions that take place during the production of steel. The study resulted in a clearer conception of the deoxidation process and the amount of aluminum lost, and it also demonstrated that the O-Probe may be useful near the end of the steel-making procedure to predict steel quality. A rough correlation was found between the steel's oxygen content just before being "tapped" into a ladle and its final aluminum content, but the correlation is weak and needs further study.

This project is a good example of a longer-range research and development task supported by the DOE program that will not immediately produce a marketable result. Economic conditions in the U.S. steel-making industry tend to discourage investments in innovative technology. Without the en-

Summary of characteristics of 5 inventions selected by the authors from the list of 41 inventions that successfully won DOE support before 1979. Of these 5, only the O-Probe, a device to optimize energy use in the manufacture of low-carbon aluminum-killed steel, is still too early in development to provide return-on-investment and return-to-society data.

	Invention	Technological level and stage of development at time of DOE grant	Stage of development at end of grant	Estimated return on investment	Est. energy saving: Bbl. oil/year equivalent; Percent U.S. total energy usage	Est. societal return: Present value of energy saved ÷ grant amount	Market success prospects
	**Wet solid fuel dryer**	Low; advanced	Substantially ready for marketing; production facility available	Approximately 98 percent per year in cane sugar industry	3.2 million; 0.03 percent	4,500	Uncertain because of depressed state of cane sugar industry; other markets need to be explored
	**Waste heat recovery from commercial cooking**	Low; advanced	Substantially ready for marketing; production yet to be arranged	Satisfactory for applications with a high product of load factor times gas price.	7.8 million; 0.06 percent	18,000	Some regions of the country offer good market; other regions are uncertain.
	**Direct-contact water heater for commercial use**	Low; midway	Substantially ready for marketing; production yet to be arranged	Greater than 19 percent per year; satisfactory for a substantial part of market	70 million; 0.6 percent	150,000	At least half of potential water heating market should be obtainable; space heating market needs to be explored.
	**Waste-water aeration control**	Medium; early in redesign phase	Prototype ready for testing and calibration	1 to 2 year payback for small municipal plants; shorter for larger plants.	4.4 million; 0.04 percent	12,000	Good for new plants; uncertain for existing plants.
	**Control of LCAK steel production**	Medium; early	Further studies being conducted	•	•	•	Effectiveness still not proven.

couragement and support of DOE, it is unlikely that Fitterer Engineering Associates and McLouth Steel Corp. could have continued this work.

Some Positive Observations

The value of the DOE Energy-Related Invention Program to U.S. energy conservation goals is clear, even judging only by the five projects just described. The first four inventions have been brought very close to marketable form or have actually been marketed. The economic effectiveness of all four appears to be satisfactory or high. Their combined estimated energy-saving potential is significant, and the energy-saving potential of the direct-contact water heater is impressive.

In the first case, production facilities already exist; the only remaining problem is encouraging a depressed industry to invest in this energy-saving equipment. Further progress will depend on economic recovery in the sugar industry or the development of other markets for the dryer. The direct-contact water heater project has already had some market success, and the inventor has just recently licensed a major manufacturer of water heaters to continue commercialization. For the next two cases, production and final marketing arrangements remain. The fifth case requires more research and development. But should it be perfected, the public investment in its support will be paid back manyfold.

These conclusions, combined with information gathered from interviews with the inventors, provide the basis for the following positive appraisal of the Energy-Related Inventions Program:

☐ It provides one of the few funding channels through which inventors can receive an objective hearing. This open channel stimulates innovative activity by inventors and small businesses.

☐ The stream of invention disclosures has been conclusively shown to contain a significant number of worthy ideas.

☐ The evaluation process used by NBS and DOE is effective in selecting particularly promising inventions.

☐ The support given to inventors has made the difference between successful development and termination of many projects.

☐ The initial indications, even if only a few of the funded projects successfully transfer to the marketplace, are that the societal benefits in terms of energy saved (and in terms of taxes earned on new profits generated) will more than repay program costs.

How to Improve the Program

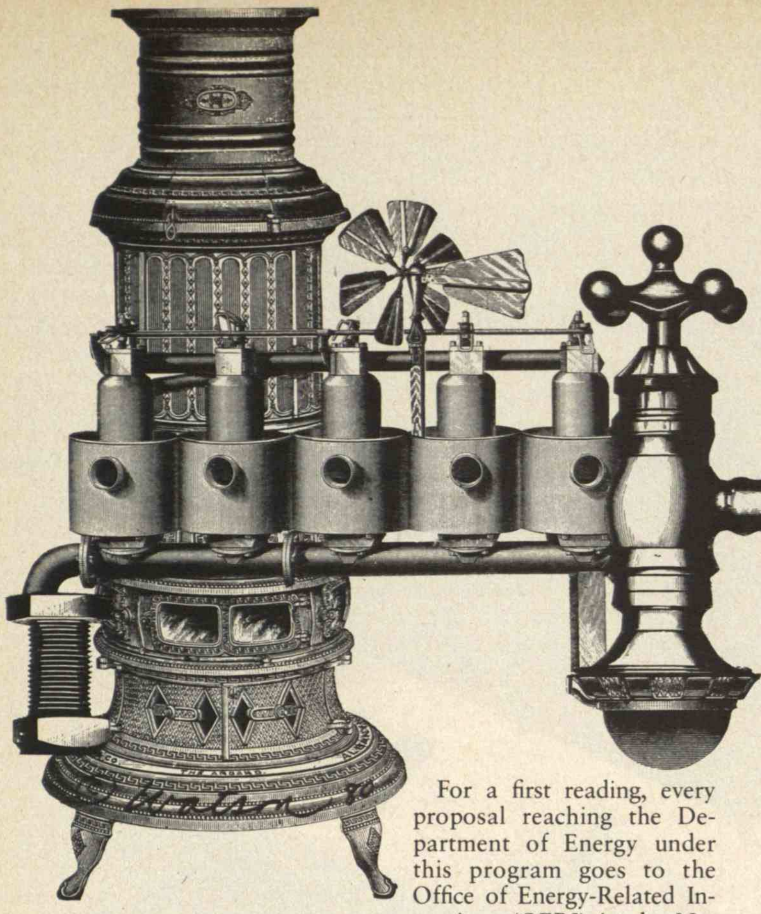
As successful as the Energy-Related Inventions Program is, improvements are certainly possible in several areas.

From the inventor's viewpoint, NBS and DOE take too long to respond to an evaluation request. The combined time for these reviews may be a year or more between the submission of a disclosure and the awarding of a grant to the successful inventor. (Inventors inadvertently may contribute to this delay with less than prompt responses.) Both NBS and DOE are working to reduce this time lag.

Consideration could be given to enabling repayment of grants through small royalties in the event of commercial success. Over time, these royalty payments could be used to partially defray the program's cost or to permit the funding of additional "higher-risk" inventions.

Although not currently a function of the Energy-Related Inventions Program, a follow-up program could be organized to monitor progress after funded work has been completed, and to refer inventors to other funding offices or agencies when appropriate. (To some extent this is already being done informally.)

The government might consider further aid to an inventor beyond a specific grant. Such aid might be in the form of counseling to develop business and marketing plans to help ensure the transfer of the technology to the marketplace.



A Status Report on OERI: Low Yield but Some High Gains

Can new inventions bail the U.S. out of its energy problems?

Probably not, but the incentives for inventors in the 1974 Federal Non-Nuclear Energy Research and Development Act (*see left*) have stimulated a veritable flood of ideas, new and old, sound and untenable. Here's a status report on the program, as presented to members of the American Society of Mechanical Engineers (ASME) late last year:

For a first reading, every proposal reaching the Department of Energy under this program goes to the Office of Energy-Related Inventions (OERI) in the National Bureau of Standards. Half are dismissed outright as being impractical; 20 percent of all the inventions submitted turn out even on preliminary analysis to be "perpetual-motion machines." In the five-year history of OERI, only 1.3 percent of the inventions reviewed have been passed on to the Department of Energy as worthy of development.

But OERI and DOE are not discouraged. "You never know when you're going to get a big breakthrough," P.J. Donohue of DOE told ASME.

Most of the inventors who have brought forth their favorite ideas are "amateurs" for whom the program is "a chance to fulfill their dreams," said Mr. Donohue. Most have never before dealt with the government, and most are financially "on the ropes" — fully extended or even overextended.

Participation by first-time, amateur inventors is inevitable, and nobody begrudges it. But Jacob Rabinow of OERI reminded ASME that most successful inventions come from professional inventors and small businesspeople, and it's these groups that especially need the financial incentives provided by the act. These people are mostly from the middle class, and in an era of high interest rates they need capital — often not very much — to finish the job of testing and perfecting their inventions . . . and to provide "a climate of encouragement," said Mr. Rabinow.

Some advice for would-be energy inventors from T.A. Coultas of OERI:

□ Look for a field in which the technology is immature. Though 25 percent of U.S. energy is consumed in transportation and another 25 percent in generating electricity, these fields don't present very fruitful opportunities for invention. Both are large, old industries with strong research and development activities, and innovation in both is constrained by extensive government regulation.

□ Though only 25 percent of U.S. energy is devoted to industrial processes, fully half the inventions reaching OERI have industrial applications. Because of the inherent diversity, there's plenty of room for new ideas, but inventors had better be familiar with the processes that form the context for their innovations.

□ Don't be stubborn. If your new idea doesn't seem to be working the way you thought it would, "don't beat your head against the wall," said Mr. Coultas. "Maybe everybody else is right and your idea isn't so great after all."

□ With so many inventions tossed out at the beginning of the evaluation process, Mr. Coultas couldn't resist a word of advice even to the ASME members in his audience: make sure your innovation is "technically apt . . . that is, that it doesn't violate the second law [of thermodynamics]." — *J.M.* □

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The Rules of Language

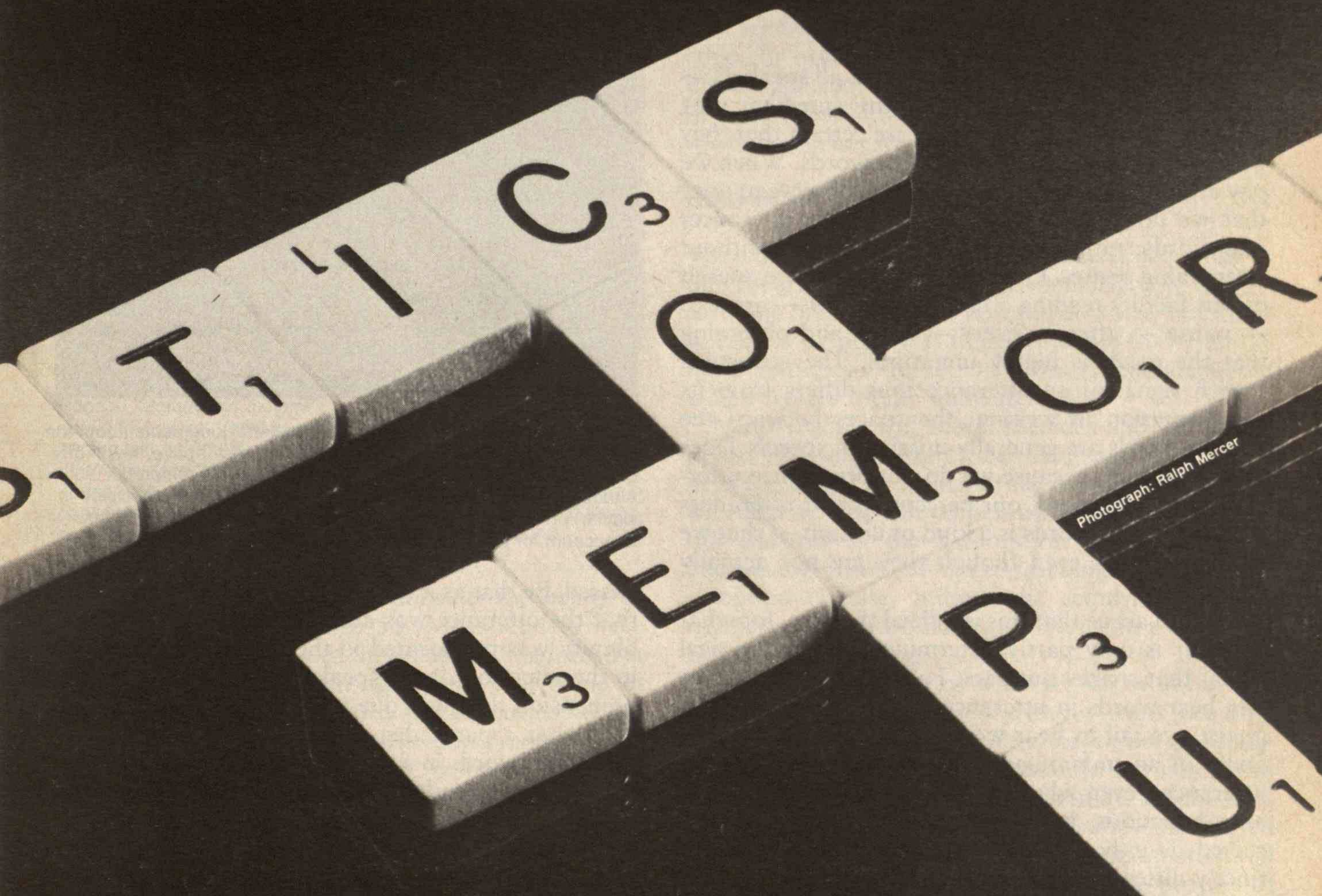
by Morris Halle

Human languages are governed by rules that are remarkable for both complexity and universality. They are clearly a function of the genetic endowment that separates humans from all other species.

The sounds that we hear when spoken to and that we emit when speaking are produced by complex gymnastics executed by our lips, tongue, velum, larynx, and lungs. The activities of these independent anatomical structures are coordinated with a precision that should be the envy of the most highly trained ballet dancer; yet this truly remarkable exercise is performed at the drop of a hat by even the clumsiest person. In contrast, even the most adroit primates have never been able to master it, despite intensive training. These facts suggest that the ability to speak is linked to our genetic endowment, that it is one of the aspects in which humans differ from all other mammals.

The gymnastic feats involved in speaking are clearly not the whole story. Speech is not just some noise that humans are capable of emitting; it is a noise that is produced to convey meaning. And how speech conveys meaning is surely one of the great puzzles that has intrigued thinkers for centuries.

Once the question of meaning is introduced, it is clear that we have to go beyond an analysis of vocal organ movements and of the acoustic signals these movements elicit. Such an analysis can tell us how the sounds of English differ from those of Finnish or Kwakiutl, but it cannot tell us why a sequence of sounds uttered by a speaker of English means something to us, whereas a sequence of sounds uttered by a speaker of Kwakiutl, or Finnish, usually means nothing. If we ask ourselves why most of us are able to understand a speaker of English but not a speaker of Finnish or Kwakiutl, the trivially obvious answer is that we know English but we don't know Finnish or Kwakiutl. But that answer leads natually to a question with a much less obvious answer: What is the character of the specific knowledge that speakers of a particular language possess through which they are able to understand one another? Although not all linguists might choose to formulate it precisely in this fashion, this question has always been central to the science of linguistics.



Photograph: Ralph Mercer

Some English "Nonwords"

thrim	lgal	dramp	pfin
platch	gnet	shripe	bdit
snork	vrag	chride	nsip

Readers whose mother tongue is English will recognize that some of these letter strings *might* be English words but some could not be. Abstract principles of word structure guide us subconsciously in our evaluation and use of these "nonwords."

Some Principles of English Word Structure

1	m n	do not figure in any clusters except *sn* and *sm; snail* and *small* are words, *gnet* is not a possible word.
2	m n l r w y	do not occupy the first position in a cluster; *platch* and *frith* are possible words, *lpatch* is not.
3	b d g	do not occupy the last position in a cluster; *bdit* is not a possible word.
4	p t k f θ	may occupy either the first or the last position in a cluster, but not both; *thrim, sphere,* and *scare* are possible, but *pfin* is not.

This list illustrates but a few of the abstract principles of English word structure. Although access to these (or similar) principles is necessary to account for English speakers' judgments about the "nonwords" above, few if any speakers will remember developing such principles in the course of learning the language.

Words: To Say and to Hear

A striking fact about all speech is that all speakers — no matter in what language — are sure that they produce words, and all hearers are certain that they perceive utterances as sequences of words. When we pay attention to our own speech, we observe at once that we do not normally break up our utterances into words; rather, we run words together without intervening pauses. One can readily convince oneself of this fact by reading a text in a way so — as — to — pause — after — every — word and observing that the result is highly unnatural. The acoustical speech signal of an utterance thus differs from its representation in writing: the spaces between the written words are generally missing in speech. Does this mean that, because we do not pronounce utterances word by word, our perception that utterances are made up of words is a kind of illusion — that we perceive words even though they are not actually there?

I would argue that this is indeed the case, for what we hear is only partly determined by the physical signal that strikes our ears. For instance, we generally hear words in utterances of only our own language; we fail to hear words in equally clear utterances in an unfamiliar language. Moreover, many utterances, even when pronounced perfectly clearly, are ambiguous, in the sense that they can be perceived as either of two (or sometimes more) distinctly different sequences of words.

A recent incident illustrates this quite well. Somebody reported to me that he had met a person with the interesting name:
Me [lbə] tory,
in which ə represents the sound of *a* in *about.* "Oh, yes," said I, "this person has the same last name as a sixteenth-century Polish king, Stefan Batory, who fought against the Turks." As I began a minilecture on Turkey's role as a major military power for many centuries, I was interrupted with the information that the person in question was female and that her first name was *Melba* and her last name *Torrey.* Although this name also provided the basis for an erudite disquisition, the opportunity somehow had passed. Be that as it may, the point of the anecdote is that the utterance was ambiguous, and that its ambiguity was not located in the acoustical signal nor in the intention of the speaker. The hearer's misapprehension thus was due to the assumption (or illusion) that a particular sequence of sounds was divided into words in a way that did not coincide with the division intended by the speaker.

Knowledge: Conscious vs. Unconscious

Since knowing words is an essential component of every fluent speaker's command of language, an obvious topic to investigate is the form in which this knowledge is internalized by speakers: What do they know about the words of their language? At first blush it may appear that the answer is trivially simple. Speakers know that certain sound sequences have particular meanings; for example, the sound sequence [dɔg] refers to the animal otherwise known as man's best friend, whereas the sound sequence [tɔk] refers to the activity of speaking.

There is more to it, however. Speakers know not only the words of their language; they also know whether a given sound sequence could or could not

The Special Roles of b, d, and g in Spanish

bajo	"low"	a[β]ajo	"below"
donde	"where"	a[ð]onde	"where to"
guardar	"to watch"	a[ɣ]uardar	"to wait for"

The consonants b, d and g are the subject of special rules in English (*see page 56*) and Spanish (*above*). Though the rules are very different in the two languages, the fact that the same group of sounds figures in the rules of two distantly related languages points toward a single set of principles governing sound groupings in all languages.

Some Special Roles of Consonants in Papago

1	wawuk[ʔ]oo[ʔ]oo	"racoon bone"
	[ʔ]u[ʔ]uhig[ʔ]oo[ʔ]oo	"bird bone"
	mawid[ʔ]oo[ʔ]oo	"mountain lion bone"
2	ba[ʔ]noo[ʔ]oo	"coyote bone"
	kaa[ʔ]woo[ʔ]oo	"badger bone"
	ceeko[ʔ]loo[ʔ]oo	"squirrel bone"

In forming compounds, the Papago language of Indians native to Arizona treats nouns ending with m, n, l, r, w, and y differently (*see 2*) from other nouns (*see 1*). These consonants also figure in the principles of English (*p. 56*). That the same consonant groups — and few others — are involved in such rules in other languages suggests that to all humans, no matter what their linguistic heritage, certain sounds are naturally related and others unrelated.

be a word in their language. Consider the strings of letters at the top of page 56. Most readers have never encountered any of these "words" before. Yet there will be widespread agreement that some of these *might* be English words whereas others could not possibly be English. Furthermore, most readers will agree as to which "words" belong where; i.e., *thrim*, *snork*, *dramp*, *platch*, and *shripe* are likely to be judged English words, while *gnet*, *lgal*, *vrag*, *pfin*, *bdit*, and *nsip* are not English. Since none of the "words" was previously encountered, the judgment cannot be the result of checking through a list of memorized words. The explanation must be that we all share some basic information about the structural properties of English words — for example, that English words never begin with the consonant clusters *gn* and *lg*, whereas *sn* and *pl* are allowed. In other words, we all share some abstract principles of word structure such as those in the illustration.

It is unlikely that any readers will recall working out such principles in the course of learning English; in fact, few speakers will claim that they are even aware of knowing such principles. Yet their ability to judge "words" such as those cited above as English or not can only be explained by the assumption that speakers of English possess this type of knowledge. In other words, this suggests that we have knowledge about our native tongue of which we are not conscious. Like Moliere's M. Jourdain, we all speak prose, but we are totally unaware of doing so.

Knowledge: Taught, Learned, and Innate

The existence of knowledge not directly accessible to our consciousness is not a particularly new discovery. One of the main purposes of Socrates' questions in Plato's writings was to demonstrate that even the most untutored among us possess knowledge of which we are totally unaware.

Many readers will accept this idea and yet be surprised that in passing on our language to our children we should be transmitting knowledge of which we ourselves are not consciously aware. Implicit in this surprise is the assumption that learning is always the result of overt teaching. But that assumption is false. Indeed, the acquisition of our mother tongue, I would argue, is a prime example of this kind of learning.

The fact that most of what we know about our native tongue is acquired without overt teaching raises a further question. All children are naturally interested in words and constantly inquire about them. But neither they nor their parents are the least bit curious about principles such as those illustrated on page 56 that govern the distribution of initial consonant clusters. Yet somehow in the process of learning English we must have learned them. How can one explain this? How can one explain, in other words, that in the process of learning the words of English we incidentally learn principles of English word structure in which we have no conscious interest and to which nothing in our daily existence might plausibly draw our attention?

The only reasonable account of how speakers come to know these principles is to attribute them not to external factors but to innate mechanisms involved in memorizing words — that is, to assume that our minds are so constructed that when we memorize words, we automatically also abstract their structural principles. We might suppose that

For one class of nouns in Kasem, a language spoken by about 80,000 people in West Africa, the singular suffix is *a* and the plural suffix is *i* (*see rows 1 and 2*). But an elaborate set of rules obscures this simple state of affairs in many instances (*see rows 3, 4, and 5*).

The Plural Rules of Kasem

	Singular	*Plural*		*Singular*	*Plural*	
1	bakada	bakadi	"boy"	fala	fali	"white man"
2	kambia	kambi	"cooking pot"	pia	pi	"yam"
3	buga	bui	"river"	diga	di	"room"
4	mala	male	"chameleon"	kaba	kabe	"slave"
5	naga	ne	"leg"	la[ŋ]a	le	"song"

human memory for words is at a premium so that every word must be stored in a maximally economical form — i.e., in a form where every redundancy is eliminated. Since the principles noted in the table (*see page 56*) capture an essential aspect of the redundancy inherent in English words, access to these principles is required to store English words in their most economical form. Different principles will, of course, be developed for different languages, but there is no language that lacks them altogether that does not place severe constraints on sequences of consonants and vowels in words. Thus the postulated mechanism that causes speakers to seek the abstract structural principles in their words will always produce a useful result.

It almost goes without saying that the propensity to search for structural regularities in the words we commit to memory is not something that we acquire from experience. Try to imagine, for instance, what sort of experiences might lead a child of average intelligence to grasp the fact that words contain redundancies that might be utilized for more economical coding. Moreover, these experiences must be common to children of all cultures, to Greenland Eskimos as well as to those whose parents are, for example, college professors. The only plausible explanation for the special way in which humans memorize words is innate: we do it in our particular way because for members of our species there is no other way.

There is of course nothing implausible in the suggestion that an organism is genetically constructed to perform particular tasks in particular ways. In fact, that is surely a major reason why a particular organism executes certain tasks very well and others poorly or not at all. Think, for example, of a kitten that shares a young child's every waking moment. At the end of a year or two the child will have acquired substantial mastery over its mother tongue, but the pet will fail to show any progress of this kind; instead, it will show great skill at catching mice and climbing trees. The reason for this is that humans are genetically different from cats, and part of that difference consists of the intellectual capacities that enable humans to acquire command of a language, presumably through special built-in features that determine, among other things, the way we memorize words.

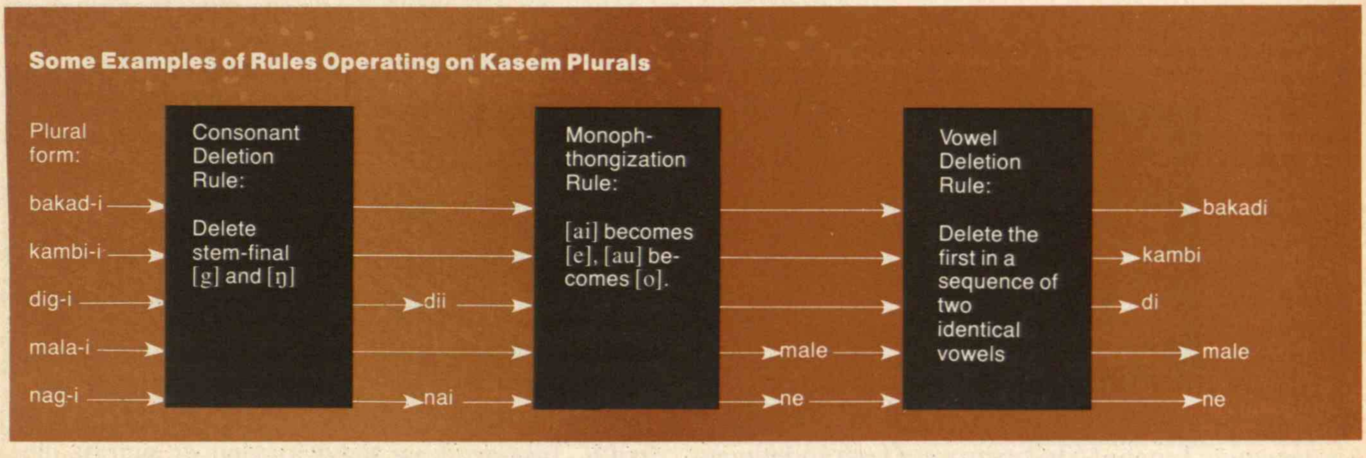
Universals of Language?

If the basis of our command of a language is genetically predetermined, then we should expect to find similarities among the principles and rules of all the different languages that are or have been spoken by humans. And we do.

In every language there are rules that affect groups of sounds rather than individual sounds, and the same groups of sounds figure in the rules of widely differing languages. For example, consider [b d g]. One of the most basic rules of Spanish phonetics states that these consonants are pronounced much as in English when they are the initial sound of a word and in certain other environments. However, they are pronounced very differently elsewhere, as shown at the top of page 57. We recall that clusters of consonants in this same class [b d g] are excluded from last position in English words (*see page 56*). Thus, this class figures in rules of two such distantly related languages as English and Spanish.

Similarly, the class of consonants [m n l r w y] receives special treatment in the Papago language spoken by Indians native to Arizona, as shown in the table on page 57; here those consonants figure in compound nouns, the second element of which is

A flow chart illustrating the application of three rules in the formation of plurals in Kasem, a West African language spoken in parts of Ghana. The plurals of all words in this class are formed by adding the suffix *i* to the stem. But a Consonant Deletion Rule, which applies first, eliminates stem-final [g] and [ŋ] in the plural. Next, Monophthongization turns [ai] and [au] into [e] and [o], respectively. Finally, Vowel Deletion eliminates one of two consecutive identical vowels. If the rules were applied in a different order, the outcome would be quite different for several forms. Unbroken arrows between rule blocks indicate that the rules are not applicable to the form in question.



[ʔ o o ʔ o o], meaning "bone." In compounding, as the illustration shows, nouns are simply adjoined. However, adjoining consonants permute position, as in the table on page 57, when the first noun ends with a consonant from the set [m n l r w y] and the initial consonant of the second noun is a glottal stop [ʔ], a sound that in English we pronounce when we attempt to distinguish *an aim* from *a name*. Thus, when *wawuk* (racoon) is adjoined to *ʔooʔoo*, the result is *wawukʔooʔoo*, but when *ban* (coyote) is adjoined to *ʔooʔoo*, the result is not *banʔooʔoo* but *baʔnooʔoo*.

The same group [m n l r w y] that figures in the Papago rule of noun compounding plays a role in English; the group is excluded from initial-consonant clusters in English words (*see row 2 in the chart on page 56*).

These examples — and experienced linguists should have little difficulty in extending the list indefinitely — show that identical groups of consonants function in totally unrelated languages. Indeed, the same groupings of sounds reemerge in the rules of language after language, whereas other groupings of sounds — e.g., [n l b k] or [θ k r g m] — are never encountered. This observation suggests that to the human speaker there is something natural about certain groupings of sounds — that they somehow belong together — whereas other groupings are unnatural and therefore never encountered. The judgment as to what sounds naturally belong together probably derives from the design of our nervous system; and that, in turn, is determined by our genetic endowment.

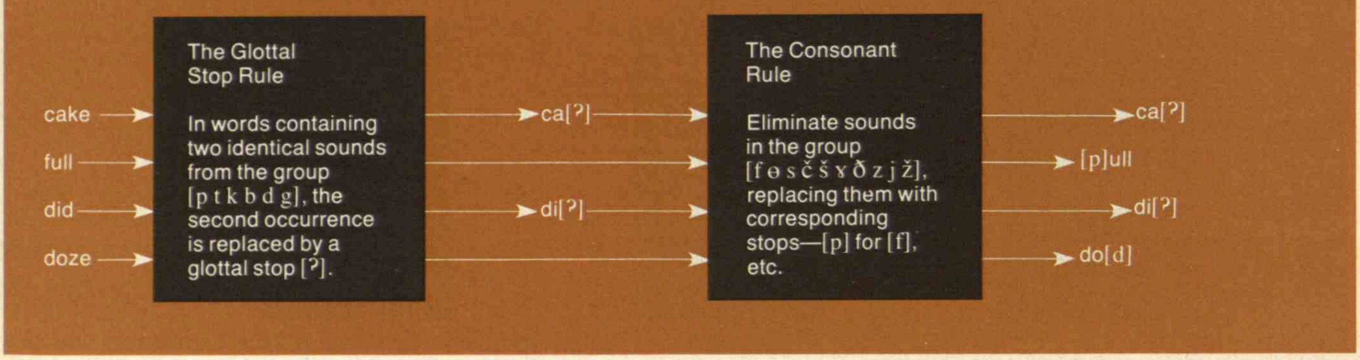
Forming Words from Words

Rules and principles of language are not at all something esoteric that only linguists and other pedants enjoy splitting hairs over. On the contrary, rules are the very stuff of which language is made, and speakers use them with the greatest ease, even abandon. Indeed, the rules and principles that determine the shape of the words in a language make up only a fraction of those regularly mastered by fluent speakers of the language.

To convey some impression of the exuberance with which languages use rules, let me briefly discuss part of the system of plural rules in Kasem, a language spoken by about 80,000 people in West Africa, primarily in Ghana. For the class of nouns shown in the chart on the facing page, the singular forms end with the suffix *a* and the plural forms end with the suffix *i*. The suffixes appear in this form in row 1 (*bakada-bakadi* and *fala-fali*). The same suffixes are involved in the other examples, but their appearance there is masked by the effects of special rules.

For example, Kasem is subject to a rule that deletes the first in a sequence of identical vowels. Because of this Vowel Deletion Rule, the plural forms

Rules of a Language Invented by Children



in row 2 are not *kambii* and *pii*, but *kambi* and *pi*.

A different rule — the Consonant Deletion Rule —accounts for the forms in row 3. This rule deletes stem-final [g] and [ŋ] in the plural. Consequently, in place of the expected *bugi* we get *bui*, and the plural of *diga* is not *digi* but *di*. The form *di* is somewhat more complicated than is first apparent. We know that the Consonant Deletion Rule would delete the *g* in *digi*, turning it into *dii*, but that is not the correct form; the correct form is *di*. There is, of course, no difficulty explaining how *di* arose: *dii* was subject to the Vowel Deletion Rule.

In the derivation of *di*, the two rules were applied in a specific order. If the rules had been applied in the reverse order, the result would have been *dii*. Since the basic form *digi* does not contain a sequence of identical vowels it could not be subject to Vowel Deletion. The subsequent application of Consonant Deletion would then produce *dii*, but to this form Vowel Deletion can no longer apply since this rule has been ordered before (not after) Consonant Deletion.

A further complication arises in the case of *mala*, chameleon (row 4). The plural form should be *malai*; instead we find *male*. To a linguist this is not strange, because linguists know numerous languages where as a result of the Monophthongization Rule, the diphthong [ai] is replaced by the monophthong [e]. In fact, English spelling still shows traces of this development; the letter sequence *ai* is pronounced *e*

Some Words in a Language Invented by Children

1	cake	ca[ʔ]	daddy	da[ʔ]y	paper	pa[ʔ]er
2	full pull	[p]ull [p]ull	pays paid	pay[d] paid	walks walked	walk[t] walk[t]
3	suit toot	[t]uit too[ʔ]	doze did	do[d] di[ʔ]	fife pipe	[p]i[p] pi[ʔ]

To give themselves a "secret" language, two children devised an elaborate set of transformations for common English words. Like the Kasem language of West Africa, the children's language was based on rules rather than rote memory — an indication, writes the author, that humans prefer even complex computation to rote memory. The relationship between the children's words and their cognates in adult varieties of American English is obvious in most instances, yet the differences were sufficient to block comprehension by adults. The [ʔ] is the phonetic symbol for a glottal stop, the sound that appears between the words *an aim* when the phrase is pronounced to differentiate it from the phrase *a name*.

as in *pain*, *maim*, and *gain*. This process is even more general in Kasem, with not only [ai] becoming [e] but also [au] becoming [o]. Now we are in a position to explain the forms in row 5 of the illustration on page 58: they are the result of the interaction of the Consonant Deletion Rule with the Monophthongization Rule. Specifically, the basic plural forms *nagi* and *la*[ŋ]*i* are transformed by the Consonant Deletion Rule into *nai* and *lai*, respectively. They are then turned into *ne* and *le* by the Monophthongization Rule.

The fact that Kasem speakers use special rules to generate the plural forms of their nouns should not seem strange in light of what we have said. What may strike the layperson as implausible is the relative complexity of the procedure — outlined only incompletely on page 59 — that appears to be involved in the inflection of Kasem words. We might well wonder whether we really go to all this trouble just to say a few words.

Implicit in this objection is the assumption that humans find it difficult to perform this sort of computation — that it would be easier to memorize such facts as the plural of *naga* is *ne* and that of *diga* is *di* than to postulate a single plural suffix *i* for all nouns in this class and to compute the different outputs according to the rules. The linguistic evidence suggests that the converse is much closer to the truth, for the Kasem example is the norm rather than the exception. Indeed, recourse to computation is so strongly favored over rote memory that speakers apparently do not have the option of foresaking rules for memorization.

Owhay Ancay Ouyay Eadray Isthay?

This natural bent for rules is expressed in a great many special uses of language. Children frequently use secret languages such as Ab-language or pig Latin, both of which are nothing but normal English to which one or two extra rules have been added. The rules for pig Latin, for instance, consist of a permutation that moves the initial consonant cluster from the beginning to the end of the word, to which the diphthong *ay* is then adjoined. Thus, *pig* becomes *igpay* and *Latin* becomes *atinlay*. These simple rules produce words so greatly at variance with standard English that children effectively possess a secret language quite impenetrable to their teachers and parents, which is, of course, the main purpose. Though to my knowledge the history of pig Latin has not been documented in detail, we know that it goes back many generations; today's speakers are not its inventors but have learned it from older children.

There are, however, numerous instances of secret languages invented by children. One such "language" was discovered about 20 years ago in Cambridge by Professor Joseph Applegate, then a member of the Department of Modern Languages at M.I.T. A couple living in his building consulted Professor Applegate about their two younger boys who, they feared, were suffering from some neurological disorder. Although they appeared to understand English, the boys were speaking a jargon that the parents found quite incomprehensible. The third child in the family, who was a few years older than the two problem children, had apparently no trouble understanding his brothers and often acted as their translator. After listening to the children for a few evenings, Professor Applegate discovered that the children were using a secret language of their own devising: by adding two rules to standard English, they were rendering their language quite impenetrable to their parents — although not to their brother.

Specifically, Professor Applegate found that the children's speech was modified by two rules absent from their parents' English. In words containing two identical stops — i.e., two occurrences of a sound from the set [p t k b d g] — the children's speech was subject to a Glottal Stop Rule that replaced the second stop by a glottal stop [ʔ]. The children therefore pronounced words such as *cake*, *daddy*, and *paper* as shown in group 1 of the table at the top of the facing page.

Second, the children's speech lacked affricates and fricatives — i.e., sounds belonging to the set [f θ s č š ɤ ɚ z j ž] were not used. In the children's language, a Consonant Rule replaced these with the corresponding stops — [f] by [p], [θ s č š] by [t], [v]

Each language has its own set of rules, and there is persuasive evidence that this characteristic of language reflects a special aspect of the human genetic endowment.

by [b], and [ð z j ž] by [d]. As a result, the children pronounced alike words that are differentiated in adult speech, as shown in groups 2 and 3 of the table.

That was not all, however. The children differentiated the stop sound that arose by the Consonant Rule from all other stop sounds: only the latter were replaced by glottal stops as a result of the Glottal Stop Rule. (Additional examples are shown in group 3.) These rules, like those in the Kasem plural formation, were applied in a definite order, first the Glottal Stop Rule and then the Consonant Rule. Thus, *did* became *di*[ʔ] by the Glottal Stop Rule, and the Consonant Rule was not applicable. On the other hand, *doze*, to which the Glottal Stop Rule was not applicable, became *do*[d] by the Consonant Rule. Since the rules are ordered, it is impossible at this point to apply the Glottal Stop Rule again.

While this system may seem surprisingly sophisticated, both it and the rules of Kasem are instances of the human tendency to use rules — with sometimes unexpected results. In the case of the Cambridge children, the tendency was used to obstruct rather than facilitate communication.

Language as Genetic Endowment

To summarize, the core of knowledge that fluent speakers have of their language has the form of rules, and these rules go well beyond what is directly observable in the movements executed by our vocal organs in speaking and the resulting acoustic signals. Each language has its own special set of rules, and these rules constitute the essence of what we learn when we acquire mastery of a given language. In learning these rules, young children require no special instruction, and much of what they — or, for that matter, any language students — learn never enters their consciousness. Underlying these rules is a set of highly abstract hypotheses about language, including such propositions as these: Speech is made up of words; words, in turn, are made up of sequences of sounds subject to definite rules; the rules affect specific groups of sounds; the same groups of sounds figure in other rules in English as well as in other languages; and the rules of any given language interact in the fashion shown by the Kasem plurals and the children's secret language.

The highly sophisticated character of these propositions excludes the possibility that they are acquired through experience. Yet the attainment of fluent command of a language by a native speaker crucially implies access to these and similar propositions. The conclusion, therefore, is that these propositions are a special aspect of the human genetic endowment, that they are part of what makes our species distinct from all others.

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Saving American Democracy: The Lessons of Three Mile Island

by

John G. Kemeny

Two hundred years ago, the founding fathers designed one marvelous political system. It is no longer adequate for the complex issues of today. Government, industry, the media, and the people, therefore, must once again form a more perfect union.

It was one year ago last April — April 11, 1979, to be exact — that my wife and I walked into the Oval Office at the White House. I had never before met the president of the United States, and if anyone had suggested, 48 hours earlier, that I would soon be accepting the chairmanship of a presidential commission, I would have thought that person totally out of his or her mind. But somehow there we were, and it led to six of the most difficult but also most fascinating months of my life. I'd like to tell you a little about the work of that commission and reflect on some serious concerns that I acquired from the experience.

Two weeks earlier, a small and ordinarily unimportant malfunction had occurred at a nuclear power plant in Pennsylvania, and it started a sequence of events that would have repercussions all over the world. As a result, President Carter appointed a commission of 12 citizens who had nothing in common except that they represented the greatest possible diversity the White House could create. We were diverse in our expertise, in our backgrounds, in our traditions, and in our beliefs on nuclear power. You may ask, as the media often did: What governs the selection of a chairperson amid such potential anarchy? My standard response was that ten years of chairing faculty meetings must surely be ideal preparation for such an assignment.

People Problems

Fortunately, we were assisted by an able and extremely hardworking staff. It was an intense education for all of us, and eventually we accumulated a body of evidence on all major issues so overwhelming that this enormously diverse commission reached a unanimous verdict. That, in a way, may well have been the miracle of 1979.

Let me summarize some of our findings for you. When we had our first meeting, four weeks after the accident, everyone was saying that it was a very simple case of operator error. The operators had

failed to recognize that a certain valve had stuck open, and failure to recognize certain other symptoms led them to turn down the emergency core cooling system. Indeed, there is no question that these omissions converted what should have been a minor incident, that you would never have heard of, into a truly major accident. But I remember vividly, at one of our earliest open hearings, the sworn testimony of these operators, who insisted they'd never been trained for anything of the kind that had confronted them. I didn't believe them at the time, but before we were through, I would learn that they spoke the truth. They in fact had not been prepared.

This convinced us that the training program for operators should be thoroughly investigated. Some of the training, it turns out, is on the job, and some of it is by contract with producers of the equipment. One witness, the head of training for a manufacturer, was very proud of the significant improvements he had made over the past five years or so in his company's program. What was the single most important improvement? we asked him. "When I came," he said, "many of the lectures were given by engineers. But engineers can't talk so that people can understand them. Therefore, the first rule I laid down was that no engineer is allowed to participate in the training of operators."

We were not totally charmed by that answer, especially when we dug deeper and discovered that all theoretical background had essentially been removed from operator training programs. They were trained for button pushing — totally adequate for normal operating conditions — but they really had not been prepared for a serious emergency. It was entirely legal under Nuclear Regulatory Commission requirements, and it became standard practice, that the operators were trained for an accident in which only one thing went wrong. They were never given an exercise where two things independently might go wrong. And in this particular accident, three things independently went wrong. The simulators are perfectly capable of generating such scenarios — before our six months were over, the Three Mile Island simulator was reproducing the accident correctly, although a bit late for the operators' benefit — they simply were not programmed to do so. When one compares that kind of training program with the typical simulator training for airplane pilots, one finds this industry substantially behind.

We were comforted for a while by the fact that many operators had come out of the nuclear navy and therefore had substantial experience. But Admiral Rickover pointed out the implications of the privacy act: unless an employee signs a waiver, the employer does not know whether he or she performed superbly in the navy or got kicked out of it. Since it has not been the industry's practice to have such waivers signed, I am sure those employees must range from the sublime to those who should never have been hired.

A second major area (that became a personal concern because of my background) was the information available to operators in the control room. I shall never forget our visit to the relatively untroubled sister plant at Three Mile Island which, incidentally, was most impressive: the equipment was immense, seemingly well built, and people understood it. Everything was extremely magnificent until we came to the control room, and there I had some rather unusual experiences. When you walked in, you saw a large wall entirely filled with little panels that serve as warnings. I think there were close to a thousand of them, if my memory serves me right, and since a canned lecture about the control room was not telling me much, I simply watched what was going on.

After about five minutes I heard a bell going off. An operator did something while the lecture went right on, so I interrupted the guide and asked him if he would mind telling us what had happened. He said an alarm had sounded, but that an alarm does not necessarily indicate something you should be alarmed about. It simply means the operator should look at something and possibly take some corrective action. Behind each one of the little plastic sheets was a light, he said, and a blinking light told the operator what the problem was. He pushed the right button, the bell stopped ringing, and they took care of the problem.

When people deeply believe that nothing really bad can happen, then clear signals of problems tend to be ignored.

So ten minutes later, when another alarm went off, by this time I was an expert. I spotted the blinking light, the operator went and looked at it and then did the right things, and normalcy resumed. Fifteen minutes later, I heard the alarm sound again and I looked all around and there was no blinking light. I did see the operator scurrying about, and he called over one of his assistants, who then started removing those little plastic parts one by one. I raised my hand again and said, "Sir, would you mind asking the operator what is going on now?" They had a whispered conversation and said, "Oh, it's nothing important. It's just that when you hear an alarm go off but no light is blinking, that means the appropriate light bulb is burned out." Then I watched for ten minutes as they painstakingly removed those little plastic sheets and did indeed find the burned-out light bulb (it was just like an ordinary flashlight bulb). They replaced it, and when it started blinking they knew what was wrong.

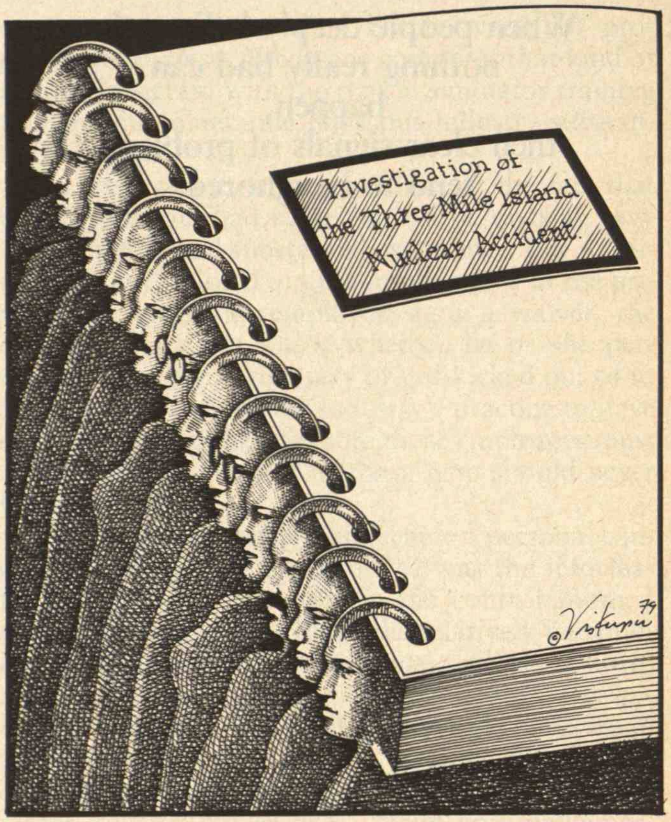
Now I'm afraid I got myself into serious trouble afterward because I remarked, within hearing distance of the media, that I did not think this particular control room represented the greatest glory of modern technology. In fact, I said it was at least twenty years out of date. I was greatly criticized for that. And rightly so, because my statement turned out to be false — we later discovered, in the documents of the NRC, a report written ten years earlier in which an expert had said that the control rooms were *then* twenty years out of date.

We started our work with the prior conviction that the big problem was equipment. But our overwhelming conclusion was that the basic equipment was amazingly good; it was the control room that was terribly designed from the point of view of the people who had to use it. The commission's attention slowly but steadily shifted, almost completely, from equipment to people. And we found that this was one of the most horrendous "people problems" we had ever encountered. We found it at three different levels. I have already told you something about the training of operators. We found a similar problem in the attitudes of management, and we found it within the NRC.

Nothing Can Possibly Go Wrong, Go Wrong, . . .

Nuclear power is an industry that seems to be hypnotized by equipment, and its equipment is darn good, but a fundamental belief persists that you can make equipment totally foolproof. Three Mile Island would seem to have dashed that notion, but when people deeply believe that nothing really bad can happen, then clear signals of problems tend to be ignored. Consider, for example, an incident at an Ohio plant called Davis-Besse in September 1977 that we investigated in considerable depth. It had very strong similarities to what would happen at Three Mile Island a year and a half later. Again, two minor malfunctions: a valve sticking open and the operators turning off the emergency core cooling system. Our big find was an engineer's document in the records of the equipment manufacturer. His report stated that they were extremely lucky the plant had been operating under low power and had recently been refueled, and therefore there wasn't a great deal of residual radiation about. He added that if the incident had occurred under different circumstances, extremely serious core damage would have resulted. His report stated, absolutely correctly, that we must give the operators clear instructions; and he had come up with instructions that would have prevented the Three Mile Island accident. Because of a bureaucratic snarl within that organization, however, the document was kicked around and never got out. A parallel story, involving a relatively low-level inspector within the Nuclear Regulatory Commission, has an ironic ending. He also worried about Davis-Besse, and he talked for months and months, to no avail, until he finally took advantage of something called the "open-door" policy: he went to see two of the commissioners, who took him very seriously and ordered an investigation. But that was March 21, 1979, only one week before Three Mile Island. It was too late.

There are other examples — one in the Tennessee Valley Authority and another in Switzerland, for instance — in which senior engineers predicted operator confusion under various plausible conditions, only to be put off or ignored by management.



We were diverse in our expertise, in our backgrounds, in our traditions, and in our beliefs on nuclear power.

Our unanimous verdict may well have been the miracle of 1979.

It wasn't any shortage of competent people that caused the inaction; it was the basic attitude that the systems were already foolproof.

Of the three "people problems," I saved the Nuclear Regulatory Commission for last. I have to report to you that the agency, at least the way it was structured a year ago, was a total disaster. It was clearly not part of the solution but a serious part of the problem. It's not that it was negligent in publishing regulations — it published tons and tons of them — but they tended to be of third or fourth order of importance, in our judgment. The really significant and fundamental issues in nuclear power seem to have eluded the NRC. For example, they missed operator training. Their inspection and enforcement arm was one of the weakest. They had the lovely habit of giving some very difficult issues a special "generic" label, thus allowing these issues to sit on the shelf. They also had no systematic way — I mean that absolutely literally and I am repeating sworn testimony by senior NRC officials — they had *no* systematic way of learning from experience. It was an agency convinced that the equipment was so foolproof that nothing bad could possibly happen; they therefore honestly believed that whatever they were doing was sufficient to assure nuclear safety.

It is not surprising, then, that in spite of the diverse backgrounds on our commission, we reached the unanimous conclusion that fundamental changes were necessary, within both the industry and the Nuclear Regulatory Commission, in people and in attitudes, if you are going to prevent future accidents as serious as Three Mile Island. And we came up with a long list of recommendations to try to significantly improve the safety of nuclear plants. At the same time, we also had to conclude that we did not find any problem that was not curable or that led us to the conviction that nuclear power is too dangerous to exist as a viable energy source. Personally, I had no particular opinion on nuclear power, one way or the other, before chairing this commission. I do have an opinion now: if recommendations like those we came up with are implemented during the next few years, I think nuclear power can be one of the energy alternatives available to humanity. I am equally convinced, however, that if recommendations like ours are not implemented — if a year from now it is business as usual — then the nuclear power industry will put itself out of business, a victim of its own attitudes. This is why we recommend a permanent watchdog committee for nuclear power, which I understand will be set up very shortly, so that the American people can know whether these recommendations are being seriously pursued.

Life on the Frontiers of Science

As I watched our own commission struggle through six months of very, very hard work to reach agreement on one small piece of the energy problem — one accident at one nuclear power plant — and as I watched the federal scene, I began to have tremendously serious worries: how will our nation be able to face up to the problems of the immediate future, and how will we ever devise effective solutions to our immensely complex problems?

The 1980s are certain to be a decade of decisions. They will be difficult and they will often be painful. Many of our problems have no simple or pleasant solutions and will require sacrifices from all of us. Certainly energy and inflation are two problems that come immediately to mind, and there are many more. Fundamental changes in the health care system of the United States may lie ahead, for example, and I hope some fundamental changes in our transportation system as well. I recently made a list of such problems to isolate what features they have in common, and I observed six:

☐ Any one of these problems is vastly more complex than Three Mile Island. And it was difficult enough — extremely difficult, in fact — for 12 honest, hardworking, and bright individuals to come to a consensus on that.

☐ The problems require significant technical input from scientists, engineers, physicians, economists, and many other kinds of experts.

☐ The problems cannot be solved piecemeal. You cannot have a little piece here and a little piece there and hope that they will fit together like a jigsaw

puzzle. They require a systems approach — an overall plan.

□ These problems must be solved on a national scale. In energy, for example, this nation can no more survive half energy-rich and half energy-poor than it could if half the nation had plenty to eat and the other half were starving.

□ Because of the sacrifices that we may be called on to make, plans cannot be implemented without a substantial national consensus.

□ Someone will have to make the choices for us among the existing alternatives. That is presumably the role of the president and Congress, but what worries me after my Washington experience is that I do not see an effective process in place for making those decisions.

Let me go into a little more depth on some of these points. Consider technical input, for example. There was a time when if someone asked me for information on science, I'd say, "Go ask a scientist." And if they said, "Which one?" I probably would have replied, "As long as you get a good one it doesn't matter which one, because if the question lies within the scientist's area of expertise and he or she investigates the problem long enough, the scientific truth will be obtained." I still believe that, but it's not always of practical value because some of the technology we use is at the very frontiers of scientific knowledge.

Our commission ran into this problem twice, once in the physical sciences and once in the biological sciences. In the former case, we tried to go through a hypothetical calculation: What if the accident had proceeded further than it actually did and there had been a true meltdown within the system? Would the molten core have been contained or not? We contracted with great national laboratories for the answer, and they did everything they could to find it. Their answer was: We *think* it would have been contained. That is more reassuring than the alternative, but we cannot be absolutely sure because our experts just do not have enough information to answer that question with certainty.

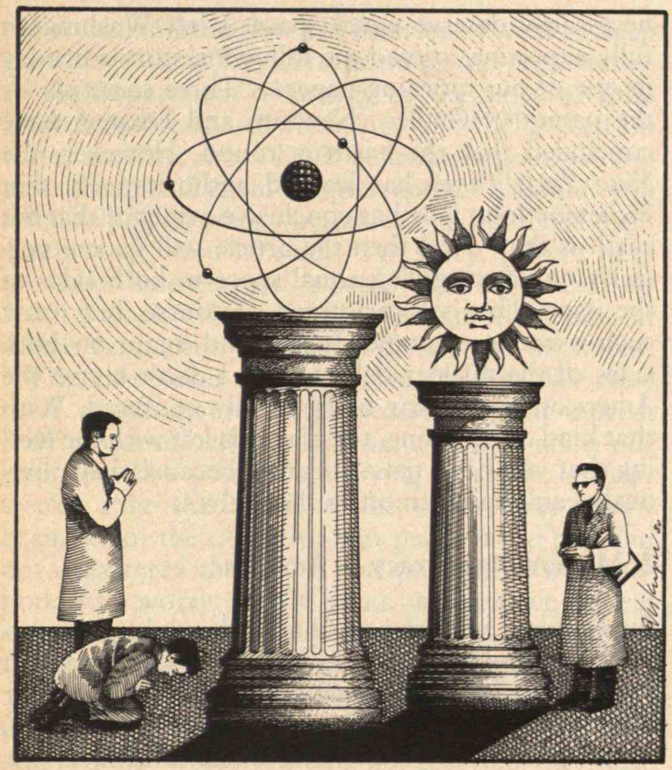
The latter case involved low-level radiation and its effects. Medical science simply does not know all the answers in this field. Fortunately, in this particular accident, such a minute amount of radiation actually got out that it did not matter much, even within a factor of 100, whose estimates on the effects of low-level radiation were correct. We could say that there will be no (or practically no) health effects from this *particular* accident. On the other hand, that problem must still be solved both generally and in the long run.

I keep talking as if the problems could be solved entirely by physical scientists. Of course that's not true. If you're talking about problems that will affect people all over the country and the world, you've got to get more input from social scientists. I have said this for at least 20 years — that the social scientists are unfortunately still lagging behind the needs of the nation. Of course, there is no magical way of getting breakthroughs in the social sciences, but we desperately need some.

In the course of our commission's work, we again and again ran into cases where emotions influenced the judgments of even very distinguished scientists. This was most disturbing to me, and I was reminded of that famous incident when Galileo was forced to recant some of his great discoveries because they ran counter to religious beliefs. Today the problem is not with religion per se, but I kept running into scientists whose beliefs border on the religious and even occasionally on the fanatical. And I hasten to add that I observed this at both extremes of the nuclear debate. These people distort their own scientific judgments and hurt their reputations by stating things with assurance that they know, deep down, could only be assigned small probabilities. They become advocates instead of unbiased advisors. This is incompatible with the fundamental nature of science and it creates an atmosphere in which there is a serious mistrust of experts: even when the hard evidence is overwhelming, if the issue is sufficiently emotional you can always get an expert to dispute it and thereby help throw all of science into national disrepute.

The Media and the Message

But suppose, somehow, we do get scientific consen-



I kept running into scientists whose beliefs border on the religious and even occasionally on the fanatical.

sus. How do we then conduct a significant national debate, at least with those citizens willing to listen and think? It's not possible to do that without getting the issues out to millions of people, and that means the media. Since I'm about to say some very nasty things about the media, let me immediately admit to some notable exceptions. But I underline that they are exceptions and not the rule.

The worst handicap to getting serious issues before the American people is commercial television. Our very distinguished commentators are specialists in describing enormously complex issues in one minute. I've even learned what "in-depth treatment" means: you get a full five minutes, with only two commercial interruptions. Even public TV, which today competes with commercial TV for the same markets, has started using some of these techniques. And while public television still gives better treatment, it also leans toward what will attract audiences and not necessarily toward what is most educational or best for the nation.

So one would hope to do better with newspapers. I had some disillusionment in that area, too, as our investigation proceeded. Only the most responsible papers will print an entire story, and you get it only if you read to the bottom of page 79 (or whatever). If you stop halfway through, you still have read only the headlines and the most sensational part of the story, and you may get a totally biased view of what actually happened. Another problem is the choice of visual images, something our commission got more and more upset about while investigating Three Mile Island. Those cooling towers were featured everywhere as horrible scary towers, and many papers depicted them as sources of radiation. But in that entire plant, the cooling towers are probably the least important features. They are not connected to the nuclear part of the plant, and plain, ordinary, harmless steam comes out of them. But the visual image the papers produced was large and scary, and therefore they became a symbol of Three Mile Island.

When it came to treatment of the presidential commission, most of the national and local media were both fair and kind to us. For some reason or

other they liked us, and I left Washington with a sense of euphoria about how well we had done. It was only after I managed to get some rest and perspective that I began to ask myself, "Okay, given that the media really were on our side, what did the average American learn from us?" I concluded that he or she hasn't the foggiest notion of most of our findings. One or two of our recommendations made headlines because they were what media spokespeople call "sexy." Most Americans have never heard of the rest of our recommendations, and most are totally unaware that the president accepted essentially all of them.

The last event is a good object lesson on what happens in covering a story. I happened to be in the middle of it because the president was kind enough to send a messenger that morning to my office in Hanover, New Hampshire so that I'd be among the first to know the official response, point by point, to our 44 recommendations: 38 were accepted outright, 5 were accepted in modified form (probably because Congress wouldn't have passed them in the original form), and 1 relatively small recommendation was rejected as not practical. I was delighted and looking forward to the stories in the papers. But the president did one more thing that day: he replaced the head of the Nuclear Regulatory Commission. Now that is the *least* important thing he did that day — it was a symbolic move. But the major media obviously thought, "This is the big story," and there were huge headlines about the changing of the guard. They again were kind to me, with several papers featuring my statement of delight quite prominently, but unless you read to the bottom of page 79, you never discovered what it was that I was delighted about.

I saved for last what troubles me most about the media: their treatment of scientific subjects. They love controversy. And that is probably good for the American people when it is a question of political elections, when it's a matter of covering Democrats and Republicans or liberals and conservatives and giving them equal space. But this produces a strange effect when reporting scientific stories, because the two sides to every scientific "controversy" do not necessarily deserve equal space. I left Washington fully expecting to read the following story someday in one of our morning papers: "Three scientists by the names of Galileo, Newton, and Einstein have concluded that the earth is round. However, the *New York Times* has learned authoritatively that Professor John Doe has conclusive evidence that the earth is flat." And then the article will go on, perfectly unbiased, giving equal space to both sides of the issue. This is a caricature, of course, but I saw such extreme examples, again and again on both sides of the nuclear debate, that I don't blame the American people for being totally confused. With that kind of reporting, the reader is left with the feeling that you can't trust scientists because they obviously can't agree amongst themselves.

A Modern Democracy in America

But suppose we get past that and we do get a national consensus. Someone then has to choose a plan for energy, for transportation, for health care, for inflation, for whatever the issue may be.

At the moment I do not see the machinery for achieving this, and I emphasize that my observation is strictly nonpartisan — the problem is with the basic system. Perhaps my view is unduly influenced by the Nuclear Regulatory Commission, but even if the NRC isn't typical of federal agencies, the executive branch has certainly grown more and more uncoordinated over recent decades. It is gigantic, it is splintered, and it is full of jealousies among agencies when we desperately need cooperation.

Consider the response of the executive branch to the accident at Three Mile Island. It was so disorganized during the emergency that the White House had to step in and knock heads so that the different agencies could work together. Four weeks after the accident, at our first public hearing, senior officers from three major branches of the executive testified that they did not go out and measure radiation until two and a half days after the accident. Here we were, a brand-new commission confronting one of our most important charges — to estimate the health effects of the accident — and we were terrified that

the crucial information had been lost. I went to sleep greatly worried. The next morning, a representative of the Department of Energy by the name of John Deutch [professor of chemistry at M.I.T., then on leave] testified about DOE helicopters going in and measuring radiation. I interrupted, "Would you mind telling us when you started taking those measurements?" And he said, "I'm sorry, I don't have my notes here on that. It could have been 12:30 or 1:00 o'clock." I said, "Sir, the question isn't at which hour, but which day?" And he answered, "Why, of course, the day of the accident. We were there within hours of the accident." And indeed, DOE produced all the data we needed to make our estimate. The point I am trying to make is: four weeks after the accident, the other three major branches of the executive that participated still had not discovered that DOE had this crucial information. So I worry greatly about whether we have a system to pull experts together from many different fields and come up with integrated plans.

I am much more worried, however, about Congress. We received a most sympathetic hearing with senators and representatives, but generally they were poorly briefed and there was no time for in-depth discussion. I do realize, of course, that the issue of Three Mile Island — overwhelming in our minds at that moment — was for them but one of a hundred issues. Members of Congress generally have a small, young, and inexperienced staff, and they certainly cannot be experts on all hundred issues. Representatives, moreover, are continually running for reelection — an enormous drain on their energy. But beyond all that, I had the impression that Congress has particular difficulty coming to grips with issues that involve significant input from science and technology. They cannot possibly be experts (not the way they are elected), but they seem to be confused even in the *use* of experts. I recall distinguished physicists on the commission being asked not about physics at all but to make a pure value judgment, when I thought that we elect senators and representatives to make value judgements on our behalf. At the same time, some of them very freely expressed strong opinions on scientific fact. I thought that is

The executive branch is gigantic, splintered, and full of jealousies among agencies when we desperately need cooperation.

Suppose Congress designed an airplane, with each committee responsible for one component. Would you fly on that airplane? Yet we are flying on just such an energy plan.

what we have scientists for. Indeed, I had a horrible nightmare one night in Washington: the House of Representatives, by a vote of 215 to 197, had repealed Newton's law of gravitation!

My conclusion is this: I've heard many times that although democracy is an imperfect system, we somehow always muddle through. The message I want to give you, after long and hard reflection, is that I'm very much afraid it is no longer possible to muddle through. The issues we deal with do not lend themselves to that kind of treatment. Therefore, I conclude that our democracy must grow up. I'm not going to give you a magic recipe on how that will happen — I wish I had one — but I offer some thoughts that I hope will stimulate your thinking.

What's principally lacking on the federal scene, it seems to me, is the existence of respected, nonpartisan, interdisciplinary teams that could at least tell us what is possible and something about the pluses and minuses of different solutions. Take energy, for instance. What I would love to see established, with the National Academies or any other mechanism to confer respectability, is a team that will struggle the way our commission did and say, "Okay, there are lots of suggestions around, and most of them won't work. But here are six different plans, any one of which is possible. We'll tell you what each one costs, what's good about it, what's bad about it, how dangerous it is, and what its uncertainties are." At least each option would be a well-integrated, clearly thought-out plan. I would trust democracy — the president and Congress — to choose among them; but I do not trust democracy to try to put together such a plan by having each committee of Congress choose one piece of it. And if you have any doubts, think about this for a moment: Suppose Congress designed an airplane, with each committee designing one component of it and an eleventh-hour conference committee deciding how the various pieces should be put together. Would you fly on that airplane? I am telling you that we are flying on an energy plan, an inflation plan, and so on that are being put together in exactly that way.

Not unnaturally, I want to put in a plug for the role of universities, which used to play a much more important role in long-term research and in worrying about the problems of the nation. Of course, a huge cutback in spending on pure research came about under the Nixon administration. We never recovered from that, and I think it is vital that this should be restored, because some of the desperately needed brain power is spread out among the universities and we are losing a vital resource. Another role for the universities, especially seeing the difficulty today's leaders have in grappling with our national problems, is to educate the next generation of leaders so that they can directly understand and come to grips with the monumental issues of our time.

With regard to the media, I'd like to suggest that they hire some people who know something about science and technology. I would even like to go one step beyond that and make a more radical suggestion: once they hire them, allow them to speak for themselves and not through the mouths of others. There seems to be a general belief — particularly on television, but also in some of the print media — that after a scientist or engineer has been interviewed, professional writers or actors (in effect) will report it so that people can understand it. Now I'm not saying that all scientists or engineers could go out there and talk so that most people knew what they were talking about, but certainly a lot of them could do at least as good a job as those who are doing it now. There would be fewer large mistakes, and less would be lost in "translation" to the American public.

I certainly advocate some reform in the electoral process, particularly in the terms of representatives (say, from two years to four years) so they won't be continually running for office. I also suspect that something like a six-year nonrenewable term for the president might be very good. I'm not saying anything that's especially original, nor am I offering any magical numbers, but anything that would help to liberate our office holders, once elected, from the electoral process would allow them to direct more of their time and energy to the nation's problems.

My last point, and the most important one, is for our nation to recognize that the present system does not work. It was designed for a much earlier and

simpler age. Even 200 years ago, the founding fathers made choices. They opted for democracy, but they did not opt for Athenean democracy. It would have been totally impractical to use an antiquated model that called citizens into the marketplace to vote on every issue as it occurred. And yet today we have essentially the same system, now itself outmoded, that we had 200 years ago. It is time to rethink the issue, because I believe that Jeffersonian democracy cannot work in the year 1980 — the world has become too complex. I'm not advocating the abolition of democracy. What I *am* advocating is its salvation. And the only way to save American democracy is to change the fundamental decision-making process, at the federal level, so that it can come to grips with the enormous and complex issues that face this nation.

John G. Kemeny is president of Dartmouth College. He served as chairman of its Department of Mathematics from 1954 to 1966, and is well known for his pioneering work in computer time-sharing for educational purposes. President Kemeny received his Ph.D. in mathematics from Princeton in 1949, where he then taught before coming to Dartmouth. During World War II, while still in his teens, he was assigned by the Army to serve as a mathematician on the Manhattan Project, later becoming a research assistant to Albert Einstein. He is the author of more than a dozen books, including *A Philosopher Looks at Science* and *Man and the Computer*.

This article is adapted from his recent Karl Taylor Compton Lecture at M.I.T., "Chairing a Presidential Commission: Reflections."

High-Speed Geology

1 H	■	2 E	3 D	4 G	5 J	6 Q	7 S	8 W	9 M	10 T	11 O	■	12 D	13 E	14 P	15 X	16 Q	17 T	■	18 F	19 Z	■	20 F	21 K	22 X	23 E
■	24 E	25 A	26 L	27 I	28 V	29 U	30 Z	■	31 B	32 E	33 Q	34 K	35 W	36 G	37 O	38 P	■	39 E	40 V	41 K	42 D	43 T	■	44 Q	45 C	■
46 A	47 G	48 Z	49 R	■	50 X	51 C	52 P	■	53 K	54 P	55 W	56 X	57 A	58 F	■	59 X	60 N	61 S	62 D	63 T	64 C	■	65 H	66 I	67 K	68 S
69 U	70 X	71 C	72 E	73 P	■	74 I	75 Z	■	76 K	77 N	78 V	79 L	80 Y	■	81 G	82 I	83 L	84 Q	85 M	86 R	87 W	88 K	■	89 R	90 C	91 Q
92 W	■	93 C	94 F	95 M	96 K	■	97 P	98 Z	■	99 X	100 E	101 P	■	102 F	103 L	104 V	105 M	■	106 Z	107 O	■	108 J	109 W	110 U	111 M	■
112 E	113 K	114 S	115 A	116 F	117 P	118 U	119 X	120 L	121 R	122 Z	■	123 C	124 V	125 O	■	126 G	127 A	128 V	129 Y	■	130 D	131 C	132 K	133 Q	134 L	135 N
136 E	137 P	138 U	139 Z	140 M	■	141 G	142 Y	143 L	144 O	■	145 H	146 L	147 M	148 A	149 Y	150 D	■	151 C	152 E	153 H	154 M	155 V	156 X	157 F	158 K	159 D
■	160 G	161 R	162 C	163 H	■	164 H	165 Q	■	166 F	167 Y	168 R	169 I	■	170 V	171 J	■	172 E	173 T	174 F	■	175 D	176 K	177 N	178 A	179 E	180 S
181 G	■	182 K	183 H	184 D	185 E	186 Z	187 W	■	188 W	189 A	190 E	191 S	192 Y	193 D	194 L	195 P	196 U	197 T	■	198 K	199 C	200 N	201 B	202 R	203 G	204 T
■	205 W	206 Y	207 I	208 Q	209 M	210 B	■	211 H	212 O	213 Z	214 C	215 J	216 I	217 M	218 V	219 K	■	■	■	■	■	■	■	■	■	■

Complete the word definitions; then enter the appropriate letters in the diagram to complete a quotation from an article on continental drift. The first letters of the defined words give the author and title from which the quotation is taken. Black squares in the diagram indicate the ends of words; if there is no black square at the right end of the diagram, the word continues on the next line. A solution to this Tech-Crostic will be in the next issue of the Review, when another of Mr. Forsberg's puzzles will also appear. Readers are invited to comment — and to suggest favorite texts for future puzzles.

A. Reputed birthplace of King Arthur — 46 189 25 115 57 148 127 178

B. Danish aristocratic national assembly, c. 1250 — 201 31 210

C. Work of Stephen Potter, 1951 (comp.) — 214 90 162 71 123 151 93 64 45 51 199 131

D. Mildness — 175 12 42 159 130 3 62 184 150 193

E. Affliction of the arteries — 185 172 100 72 2 24 23 112 190 39 32 152 136 179 13

F. Aegean island, devastated by volcano, c. 1500 BC — 94 166 58 20 18 102 116 174 157

G. Jonathan Swift's rational horse — 81 160 203 126 47 36 141 181 4

H. Name associated with first use of punched cards for automatic control, c. 1804 — 145 164 65 183 153 1 163 211

I. A bone tumor — 66 207 74 82 27 216 169

J. German composer, 1822-82 — 215 5 108 171

K. Future-archaeology satire by Robert Nathan, 1961 (3 wds.) — 76 176 219 34 53 158 88 132 21 113 198 41 96 67 182

L. Worsen — 146 26 143 134 83 79 103 194 120

M. Trifling; unworthy of consideration — 154 105 140 85 95 147 217 9 209 111

N. Stanislaw Lem's robot constructor ("The Cyberiad") — 200 60 135 77 177

O. A young cow — 144 11 37 107 212 125

P. Horological control mechanism — 195 73 38 97 14 52 117 101 54 137

Q. A nonmetallic meteorite — 16 133 33 165 84 6 44 91 208

R. Umbrian town, Etruscan "Volsinii" — 86 121 161 89 168 49 202

S. Seagoing Indian tribe of Vancouver — 114 191 180 68 7 61

T. "What____meant" (Lewis Carroll, "Sylvie and Bruno") — 17 63 204 43 10 173 197

U. Southern suburb of Los Angeles — 138 196 110 69 29 118

V. A beginner, especially ecclesiastical — 218 170 40 78 155 28 128 104 124

W. Early name for Astatine (comp.) — 35 188 8 205 92 55 109 87 187

X. Wink — 70 56 59 119 22 50 156 99 15

Y. Ancient galley — 206 129 142 167 149 192 80

Z. Popular beef dish — 122 98 186 106 30 48 139 75 213 19

Diamond/Continued from page 11

Republicans in 1960, then it proves there's nothing all that new in politics.) Reagan complains that the American triad system of deterrence has been weakened by Carter, and Reagan proposes immediate production of an advanced bomber as well as the upgrading of existing aircraft such as the B-52. Reagan favors deployment of the neutron warhead, establishment of a military presence in the Mideast, and restoration of America's strategic military superiority. As he states his military philosophy, "It isn't weakness that keeps the peace, it's strength."

Bush was probably the only candidate to injure himself in the defense debate, stepping on the land mine of "survivable nuclear war." During an interview with Robert Scheer of the *Los Angeles Times*, Bush said that the United States could win a nuclear war because "you have a survivability of command and control, survivability of industrial potential, protection of a percentage of your citizens, and you have a capability that inflicts more damage on the opposition than it can inflict upon you. That's the way you have a winner." (Scheer is the same reporter whose persistent questioning of Jimmy Carter in 1976 got him to talk about "lust in his heart.") Bush's comments were so unusual in a presidential race — where everyone modulates words — that they dominated the news for a long time. Bush later took the more conventional GOP position: funding for the MX, the neutron bomb, and other new weapons systems.

Anderson, now running as an independent, does not fit the hard-line GOP military position. Anderson advocates more dramatic steps to reduce dependence on Persian Gulf oil. He opposes the MX missile and the B-1 bomber and calls Bush's winnable-nuclear-war thesis "appalling."

In general, technology does not play a great role in primaries because large numbers of voters expect to hear homilies. Moreover, people recognize that even presidential homilies require Congressional backing and funding for implementation.

But debates on technology in the campaign may also be unrealistic for another reason. Based on our campaign watch, the News Study Group believes that the candidates' apparent unwillingness to discuss complex issues in depth may derive from the limited knowledge of both the campaign advisors and the candidates themselves. Also, even those candidates with specific interests in certain technological issues probably risk votes by focusing on them. In primaries particularly, single-issue groups — gun enthusiasts, antinuclear activists, whoever — can hurt the candidate.

In the U.S., the words "research," "technology," "development," and "science" continue to create positive resonances with the voters. The differences among candidates, however, are not necessarily in their support of research and development. On the contrary, as Dr. Thomas F. Jones, vice-president for research at M.I.T., says, "Any reasonable administration would see the importance of research and maintain its funding at reasonable levels."

But it's possible that reason may be in somewhat short supply in the general elections this fall. Then, debates will focus almost exclusively on military and energy matters. A Reagan-Carter-Anderson race in this regard could be as bitter as the 1964 Johnson-Goldwater race. All the candidates have stands on technology issues. While the stands may differ, the lack of discussion will be near unanimous, and the presidential race will be influenced only to a small degree by the specifics of technology. Even the nuclear energy debate, important near a Seabrook, New Hampshire or a Rocky Flats, Colorado, may be lost in the clamor about Iran, inflation, and the economy.

Presidents possess real, as well as symbolic, power to determine the level of research during their administrations. The funding cutbacks in research and development during the Nixon administration have not been fully restored even now. Our fear is that the next president will be distracted from long-term concerns by the tidal wave of more immediate events. □

Solution to May Crostic

When the rain has wetted the kite and twine, so that it can conduct the electric fire freely, you will find it stream out plentifully from the key on the approach of your knuckle. At this key the phial may be charged . . . and thereby the sameness of the electric matter with that of lightning completely demonstrated.

Benjamin Franklin, in a letter to Peter Collinson, Oct. 19, 1752. Reprinted in Westfall & Thoren, "Steps in the Scientific Tradition, Wiley, 1968

A. Bukharin
B. Ftatateeta
C. Rimpfischhorn
D. Attitude
E. Nauhcampatepetl
F. Kirkcaldy
G. Loge
H. Imbricated
I. Nephelococcygia
J. Twenty-twenty
K. Oshkosh
L. Pterodactyl
M. Efferent
N. Thorkel Dyrthil
O. Ethylene
P. Romancement
Q. Cuttlefish
R. Offwhite
S. Little Diomede
T. Lawes
U. In the way
V. Nineteen Eighty Four
W. Stretches the Truth
X. Oldham
Y. Nashe

Trend of Affairs

Trends This Month

Defense

Inedible Fruits of Military Spending

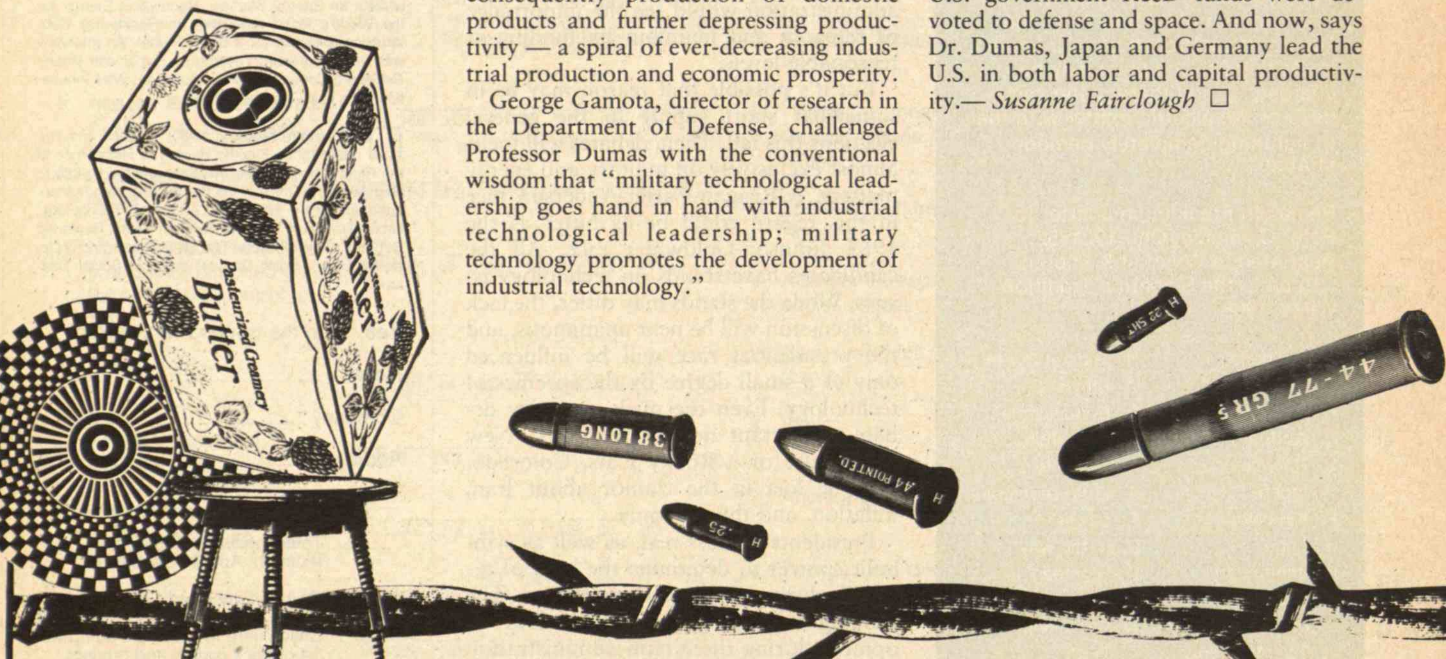
President Jimmy Carter, fighting inflation and yet determined to increase U.S. military spending, is like Alice trying to serve the quarrelsome Hare and Hatter at a single table in Wonderland. Inflation results from low productivity, and our ability to improve productivity is jeopardized by the diversion of technological prowess to defense.

Indeed, political economist Lloyd Dumas of the University of Texas at Dallas told the American Association for the Advancement of Science earlier this year, much of today's inflation may be the result of an enormous drain of scientific talent from civilian to military enterprises over the past three decades. Dr. Dumas' conservative estimate is that at least a third of the nation's scientists are employed in the development of military-related technology. The growth rate of U.S. labor productivity was cut in half between 1965 and 1978; unable to offset increases in the cost of materials and labor through productivity improvements, industries passed on their higher costs to consumers, thus fueling inflation. Customers turned to lower-priced imported substitutes, thus reducing demand and consequently production of domestic products and further depressing productivity — a spiral of ever-decreasing industrial production and economic prosperity.

George Gamota, director of research in the Department of Defense, challenged Professor Dumas with the conventional wisdom that "military technological leadership goes hand in hand with industrial technological leadership; military technology promotes the development of industrial technology."

Not so, declared Dr. Dumas, "Conceptually, it is difficult to see how directing attention to one area of technical research must routinely produce an *efficient* generation of knowledge pertaining to a completely different area. One cannot hope to understand the fundamental role of slowing technological progress in producing present and ongoing productivity deterioration until a clear distinction is made between civilian- and military-related technological development."

During the 20-year period beginning in 1953, the U.S. lead in major innovations steadily declined; the "patent balance" of the U.S. fell by about 30 percent during the last half of that period. It is no coincidence, says Professor Dumas, that patent-leading countries like Japan and West Germany made substantially higher government investments in civilian research and development — 75 percent and 60 percent, respectively — than the United States during this period. Investment in military and space projects by these countries averaged 3.3 and 22 percent, respectively, of total government research and development expenditures from 1961 to 1972; in the same period, 76.6 percent of U.S. government R&D funds were devoted to defense and space. And now, says Dr. Dumas, Japan and Germany lead the U.S. in both labor and capital productivity.— *Susanne Fairclough* □



Military Spending: The Right Solution at the Wrong Time

Does economic reasoning justify the arms race? Yes, according to at least one celebrated economist. Trouble is, the applicable theory went out with saddle shoes.

In the post-World War II period, explains John Kenneth Galbraith, emeritus professor of economics at Harvard University, heavy military spending helped counter the deflationary and unemployment effects of civilian underinvestment. In filling that void, it gave the economy a much-needed boost. Market conditions in the U.S. have changed, but the rate of military spending has not, and it is now a powerful contributor to inflation and a colossal drain on federal funds that could otherwise be allocated to public services and modern urbanization.

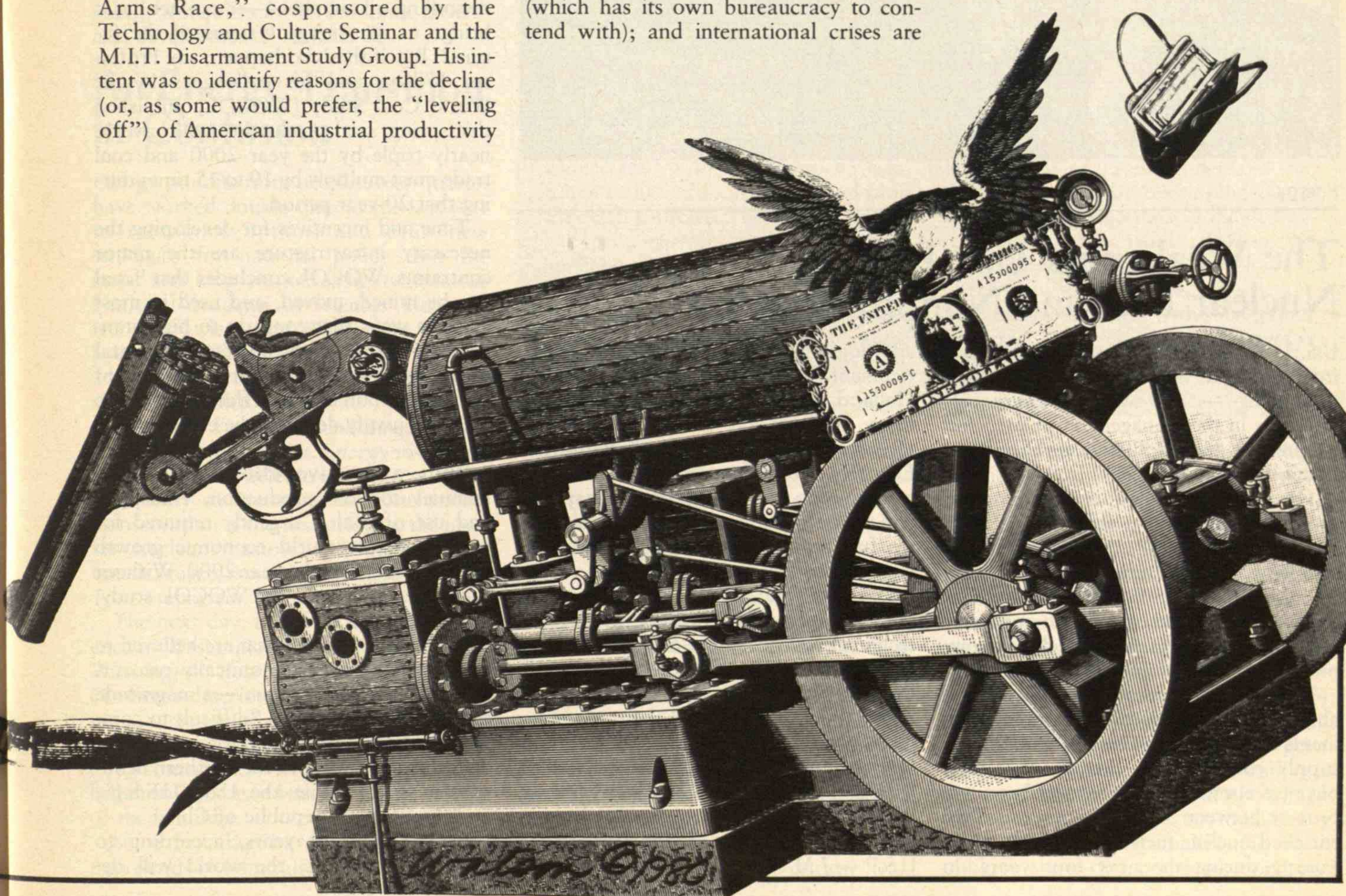
Professor Galbraith made these and other observations at a recent forum at M.I.T. on the "Economic Effects of the Arms Race," cosponsored by the Technology and Culture Seminar and the M.I.T. Disarmament Study Group. His intent was to identify reasons for the decline (or, as some would prefer, the "leveling off") of American industrial productivity "without exaggerating any one factor." In addition to the *outmoded economic theory* theory, he offered these:

□ *To the losers belong the spoils.* By an ironic twist, we gave the nations we defeated in war the wherewithal to outflank us in the world marketplace: for example, U.S.-supported plant construction and limits on military expenditures in Japan and West Germany (at first explicitly imposed by the Allies and later self-imposed) that enabled large investments in civilian production. Meanwhile, however, the U.S. plowed much of its own capital into the "war industry."

□ *Bureaucracy power.* Conventional wisdom has it that military spending is the result of excessive corporate clout. In Professor Galbraith's view, this is the effect, not the cause; it is really a response to a higher authority — an entrenched bureaucracy. "The bureaucratic power of the Pentagon," he said, "is far greater than that of the aerospace industry." The military budget, therefore, is not necessarily a function of our strategic position with respect to that of the Soviet Union (which has its own bureaucracy to contend with); and international crises are welcomed, somewhat perversely, as reinforcing the need for higher levels of spending.

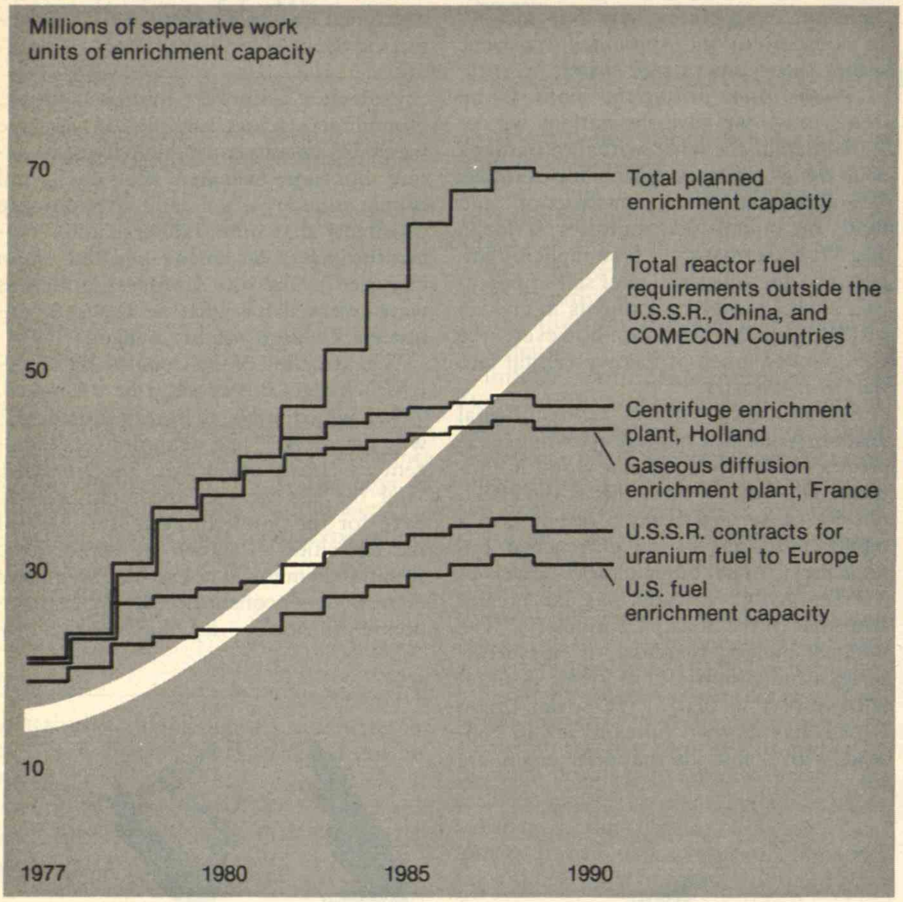
Professor Galbraith discussed other, nonmilitary factors such as *old age* (the inevitably declining productivity of a mature but unrejuvenated economy), and *simple stupidity* ("we can't overlook the possibility that some Japanese auto companies are less meat-headed than Chrysler"). But his strongest criticisms were reserved for what he views an unnecessarily large military budget.

What fraction of the Department of Defense's budget *is* necessary? he was asked. "That which is not militarily indulgent," was the reply. "The definition of 'indulgent' is clearly subjective," he admitted, "but the less we use, the more we will have for the South Bronx. The needs of the big cities — shown by the decayed situation in many, if not most, of our great metropolii — constitute our highest economic priority." — *S.J.M.* □



Karen Watson

The growth of non-Communist nuclear fuel enrichment capacity. (A 1,000-MWe light-water reactor requires about 240,000 separative work units [swu] of enrichment at startup and about 110,000 swu annually thereafter.) While the U.S. has built its nonproliferation policies on the assumption that it could control world markets for nuclear fuel, other nations have quietly built up their uranium enrichment facilties so that the U.S. no longer has a near-monopoly — or even a dominant — position in fuel enrichment. Only by simplifying the export requirements in the 1978 Nuclear Nonproliferation Act can the U.S. retain its influence on proliferation.



Energy

The Weakening U.S. Role in Nuclear Fuel and Nonproliferation

U.S. leverage in the international market for enriched nuclear fuel is rapidly weakening — and with it direct U.S. influence in the management of such fuel to prevent the proliferation of nuclear weapons.

The 1978 formulation of U.S. anti-proliferation policy — the Nuclear Nonproliferation Act — is based on the assumption that by retaining a dominant position in the enrichment of nuclear fuels, the U.S. could continue to impose its will on other nuclear powers. But U.S. supremacy is almost a thing of the past.

These days nations that do not want to abide by the nonproliferation requirements that the U.S. writes into nuclear fuel supply contracts can literally take their business elsewhere. The Soviet Union will provide between 50 and 80 percent of the enriched nuclear fuels needed by Western Europe during the next four years. In addition, there is excess capacity in enrichment facilities recently completed in Holland, France, and (soon) West Germany. In short, say Thomas L. Neff and Professor Henry D. Jacoby of the M.I.T. Energy Laboratory, as of this year the combination of excess European capacity and Soviet exports is sufficient to fulfill all the fuel requirements of the world's nuclear reactors outside of the U.S.

Drs. Neff and Jacoby are alarmed but not dismayed. They propose a range of technical changes in the Nonproliferation Act that will make the processes by which the U.S. grants fuel contracts to foreign nations less complex and their outcomes more predictable. In general, they want foreign nations to be assured of export licenses "so long as there is no evidence that the prospective purchaser has been in violation of its prior agreement with the U.S." — *J.M.* □

Coal: World Energy Ace-in-the-Hole

Coal now provides over 25 percent of the world's energy, and it is likely to have a much larger role in the future. Indeed, more than half of the additional energy the world will need to continue economic growth in the next 20 years must come from coal.

It was three years ago that an M.I.T.-based study of alternative energy strategies emphasized that world oil supplies would fall short of demand well before the year 2000. Now a similar study, drawing on energy experts from 17 nations under the direction of Carroll L. Wilson, Mitsui Professor in Problems of Contemporary Technology, Emeritus, has reached a "cautiously optimistic" conclusion about coal as a world energy alternative.

World coal resources are so large that coal can have a significant role as an energy source in the twenty-first century, and meanwhile — by relieving pressure on dwindling oil supplies — it can act "as a bridge to the energy systems of the future." But if that's to happen, say Professor Wilson and his colleagues in the World Coal Study (WOCOL) published this spring, coal production will have to nearly triple by the year 2000 and coal trade must multiply by 10 to 15 times during that 20-year period.

Time and incentives for developing the necessary infrastructure are the major contraints. WOCOL concludes that "coal can be mined, moved, and used in most areas in ways that conform to high standards of health, safety, and environmental protection. . . . The present knowledge of possible carbon dioxide effects on climate does not justify delaying the expansion of coal use.

"But a massive effort to expand facilities for the production, transport, and use of coal is urgently required for even moderate world economic growth between now and the year 2000. Without such increases," says the WOCOL study, "the outlook is bleak."

World coal reserves that are believed to be technically and economically recoverable total 660 billion tons — a magnitude that WOCOL admits is "difficult to comprehend fully." These deposits are widely distributed throughout the northern hemisphere, most within the U.S., U.S.S.R., and the People's Republic of China.

In the next 20 years, according to WOCOL scenarios, the world will de-

mand a prodigious 103 billion tons of coal — 25 billion tons in the U.S. alone. By the year 2000, 1.2 billion tons a year could be used to generate U.S. electricity — an unprecedented annual growth rate of 5 percent between now and then. Perhaps 200 million tons a year will be used for other industrial purposes, and nearly the same amount will be used to produce synthetic fuels — both gaseous and liquid.

But, says WOCOL, "the full effects of the switch to coal will not be seen until the early decades of the twenty-first century." The real problem for the twentieth century is to pave the way for this increasing reliance on coal, and that will require a total world investment of $1,000 billion (1978 U.S. dollars). Though WOCOL says that level of investment is "well within the combined potential capacity of domestic and international capital markets," it won't happen spontaneously. Professor Wilson and his colleagues warn that only "a recognition of the urgent need for coal and determined actions to make it available in time will ensure that the world will continue to obtain the energy it requires for its economic growth and development." —*J.M.* □

Coal and CO_2: Not a Non-Problem?

Even while the World Coal Study's results (*see left*) were being compiled, Professor David J. Rose, an energy expert who held M.I.T.'s prestigious Killian Faculty Achievement Award for 1979-80, was telling his audience in a Killian Lecture that "many grave environmental and health effects [that] accompany the use of coal have been selectively ignored. The worst of these," he said, "is carbon dioxide buildup.

"Carbon dioxide (CO_2) comes unavoidably from burning carbonaceous material, and there is no realistic means of control other than limiting the use of these fuels. Again, coal is the worst offender per unit of energy, though oil and natural gas, with about 70 and 50 percent (respectively) of coal's carbon dioxide emissions, also make important contributions. Also, the much larger resources of coal make it potentially most hazardous. Atmospheric carbon dioxide helps to regulate the temperature profile of the earth's atmosphere and surface. This happens because although the atmosphere is transparent to the wavelengths of incoming solar radiation, the CO_2 and water vapor absorb the long-wave infrared radiation (heat) reradiated from the earth's surface. They thus trap heat and raise surface temperatures (the 'greenhouse' effect).

"The present increase in atmospheric carbon dioxide is accurately and universally observed at Hawaii and the South Pole; if present trends continue, the atmospheric carbon dioxide will double within two generations. Almost all analyses predict an average warming between 1° and 5°C, with extra warming in the polar regions.

"Government energy planning throughout the world virtually ignores this problem. But it is pressing now because the fundamental changes that would constitute a remedy take a long time to bring about. For example, global agriculture, by complicated geographic, social, and institutional arrangements, matches crops to particular areas. Experience shows that total production decreases in times of changing climate, because neither the pattern of land nor the fertility can change rapidly enough. The system has inertia.

"While the world energy problem is severe, the world food problem is even more critical, with fluctuations of a few percent in the global food production bringing misery to many. Also, the perception of some countries gaining and some losing will aggravate international tensions.

"Thus, ahead lie the hard tasks of reducing substantially the combustion of coal, oil, and natural gas worldwide in the face of growing demand for them, especially by developing countries. The first and most difficult task may be to make people all over the world aware of the problem. No very effective institutional mechanisms appear available to deal with such global matters." (*Copyright 1980 by David J. Rose*) □

An Energy Transition in Confusion

Energy pundits from nearly every quarter have worked double time in the last year to reexamine options and offer new strategies for national policy. But the latest and long-awaited insights from the National Academy of Sciences' Committee on Nuclear and Alternative Energy Systems (CONAES) seems merely to have added another measure of confusion to an already muddled field.

The *New York Times* obtained a copy of the CONAES report, *Energy in Transition,* before its release and ran a front-page story summarizing the conclusions. Conservation is the first priority, the need for nuclear reactors will decline, and breeder reactors may not be necessary, the *Times* reported.

The next day, based on a press conference in Washington, newspapers from the *Washington Post* to the *San Francisco Chronicle* described the report as forecasting greater use of coal and nuclear, rapid breeder reactor construction, and little, if any, contribution from solar energy. It began to look as if wisdom lay in the eye of the beholder.

Since then, there have been several rousing rounds of rebuttals, clarifications, and accusations from participants in the study, as well as from various energy partisans.

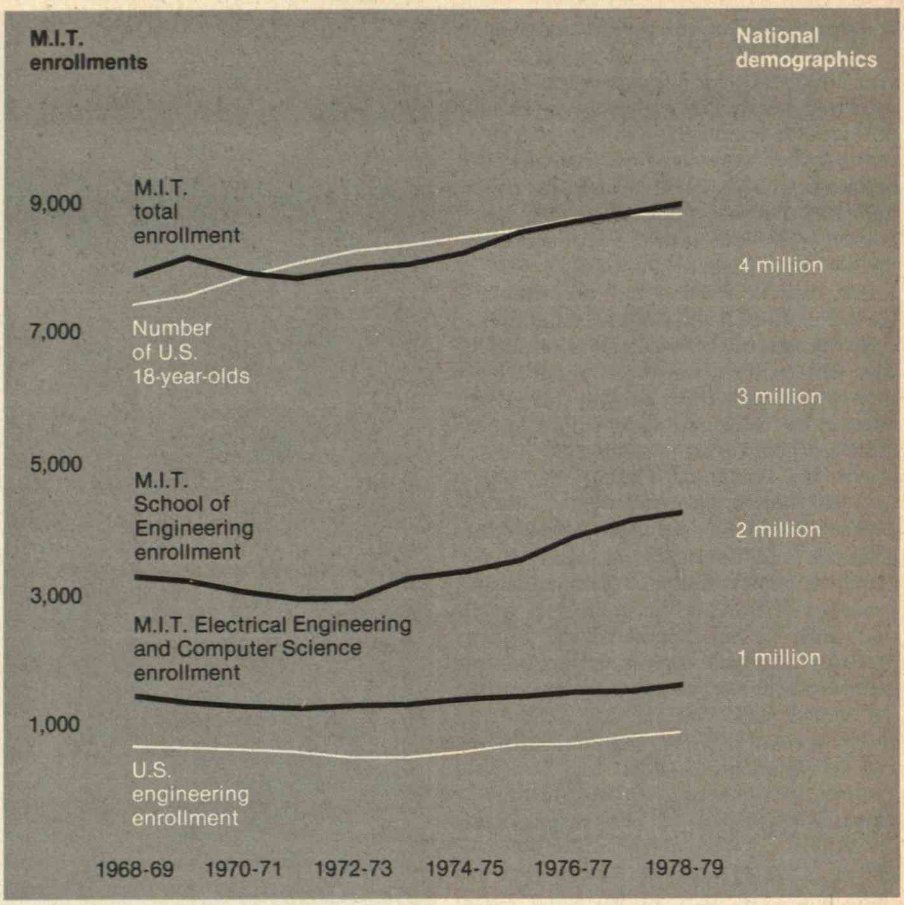
Why all the confusion? And, more directly, what does all this portend for our nation's energy policy?

For one thing, it appears that few people — certainly few reporters — actually looked at the 783-page report that took four years and $4.1 million to complete. Though both the study and the 9-page summary passed out at the press conference are riddled with conditionals and qualifiers, the emphasis on conservation as a first priority is clear, and just as clearly disregarded in many newspapers.

Just for the record, the other "observations" the CONAES report offers to decision makers focus on "the critical near-term problem of fluid fuel supply, the desirability of a balanced combination of coal and nuclear fission as the only large-scale intermediate-term options for electricity generation, the need to keep the breeder option open, and the importance of investing now in research and development to ensure the availability of a strong range of new energy options sustainable over the long term."

The report's scenarios hinged on specific energy-demand growth rates and energy price estimates — all assumptions that are uncertain at best. The study's assertion that solar energy will not contribute significantly to the national energy supply, for example, applies only in the unlikely event that prices for competing

The national pool of 18-year-olds available for college enrollment, compared with the number of students enrolled in engineering nationally, in the M.I.T. School of Engineering since 1968, and combined enrollment at M.I.T. in electrical engineering and computer science and engineering programs. (*Data: National Center for Educational Statistics, Engineer's Joint Council, M.I.T. Registrar's Reports*)



energy sources remain low and no pro-solar subsidies or policy initiatives take effect. To report the conclusions without the assumptions skews even the most cautious energy forecasting.

Another feature of the study that went widely unacknowledged is the presence of dissenting views, neatly spliced into the summary and attached as an appendix to the full report. These arguments, submitted by authors who simply could not contain their disagreement, lend perspective to what were reported as clear-cut prescriptions from the committee. Clearly these arguments are just tip-of-the-iceberg indications of the underlying dissension on the committee.

According to Harvey Brooks, CONAES cochairperson and professor of technology and public policy at Harvard University, the writing of the final document took on aspects of a treaty negotiation. Still, several CONAES members contend that the report bares a prejudice in favor of nuclear power without adequately stressing the committee's divergence on this point. John Holdren, director of the Energy and Resources Program at the University of California at Berkeley, is one of the most vocal dissenters. "The obstacles hindering coal and nuclear are different," Holden writes. "They are environmental and sociopolitical more than technical and economic, but they are neither less real nor more easily circumvented than the liabilities of the renewables. . . . The notion that society should prefer the former to the latter may be the majority view of this committee, but that position should be recognized as a value judgment that does not deserve to be paraded as the 'only' possible outcome."

Such divergences from the report are a very important part of the picture, according to contributor Kenneth Boulding, emeritus professor of economics at the University of Colorado. "They should be taken not as a sign of failure but as a sign of the immense difficulty and complexity of the problem and as pointers toward further work."

So amidst all the clarifying and qualifying, what can we surmise from the four years of work that went into *Energy in Transition*? "If there is any conclusion to this report of practical significance," Boulding writes, "it is that there is a strong case for having our eggs in as many baskets as possible." Says John Holdren, "we know that the U.S. energy future will be just what we choose it to be." Maybe that *is* difficult to report. — *Valerie Dow* □

Help Wanted

Microcircuit Designers: The Circuit Shortens

The size of the pool of specialized engineers responsible for the continuing miniaturization of electronics circuitry is ironically showing signs of dwindling.

The likelihood of further innovation and enhanced productivity in the field of very large-scale integrated (VLSI) circuitry rides on the skills of a small group of these specialists — only about 2,120 in 1978 — as does the future of the ubiquitous applications of VLSI technology. Only about 150 of each year's new graduates in VLSI design and process areas remain in the field for more than three years, writes I.R. Saddler, manager of very high-scale integrated circuitry (VHSIC) at Motorola, Inc., in *Military Electronics/ Countermeasures* magazine. Thus, the continuing graduation of key personnel from engineering schools is needed to ensure adequate creative resources.

Mr. Saddler warns that curtailment of growth in VLSI technology will be due to "a limitation in brain power" and not to "shortages, real or imagined," in materials. So serious are the implications for this field that he questions if the development of U.S. semiconductor technology can continue at its present rate for long.

The semiconductor industry hasn't felt the worker crunch yet. It has grown at a rate of 20 to 30 percent annually for the past few years and now accounts for about 5.3 percent of the U.S. gross national product, says Mr. Saddler. But those halcyon days may be numbered. There may be lean times soon for industry and military staffers trying to maintain the present size of the work force (*see graph*). This national problem is developing despite the fact that the fraction of 18-year-olds entering college has increased steadily since the mid-1950s, and no change in this trend is imminent.

On the bright side are several harbingers of hope:

□ "Most of the major semiconductor houses have some form of engineer training program," notes Mr. Saddler.

□ In 1976 there were about 20 schools "with some processing and design capability," and that number may well increase as the need for people with this training is felt.

□ Learning to produce semiconductor devices "needn't be done on the latest equipment," he observes, promising some capital relief for financially limited academic and industrial training programs.

Computer-aided design techniques should be developed and improved to free human VLSI designers for more creative tasks. Paradoxically, the most efficient use of a VLSI silicon chip is produced by hand layout — not computer design. But the increasing complexity of these chips is leading to the day when "it will be impossible in any reasonable time to do a layout," says Mr. Saddler. He looks toward current efforts by the Advanced Research Projects Agency to inject a "bright hope for less-limited growth" into the field of VLSI.

The stakes riding on these lowly chips are high indeed. Quips John D. Vance, publisher of *Military Electronics/Countermeasures*: "What stands on spindly legs, crouches in flat shells, and holds the key to U.S. defense technology supremacy? . . . The proverbial semiconductor chip!" — *L.A.P.* □

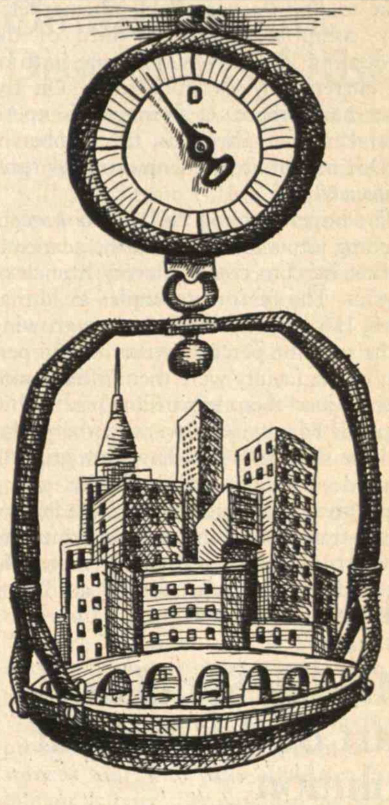
Physics in Balance

The "crisis" of the 1970s has run its course, and the supply and demand for physicists is now approaching a balance after an era of significant surplus.

For most of the 1960s, the graduate schools "spewed forth too many physicists for the available jobs"; perhaps as many as 10,000 left the field to work in other areas of science and engineering, says Lee Grodzins, professor of physics at M.I.T. Now that's changed; the number of Ph.D.'s awarded annually in physics is down from 1,700 in the early 1970s to just over 1,000 in 1979. The physics labor force will grow by only 2 percent a year in the 1980s compared with over 7 percent a year in the 1960s. As a result, says Professor Grodzins after an extensive survey of industry, university, and government laboratories, the number of new jobs "should be about equal" to the number of Ph.D. graduates in physics for the next five years.

Technomass

Technology Weighs In



Richard A. Goldberg

How much has technology changed the face of the United States?

Carnegie-Mellon University students in a course called Analysis, Synthesis, and Evaluation have answered that question this spring by calculating the U.S. "technomass" — the weight of all existing U.S. works of technology. The total comes to 579.931 billion tons — about 2,636 tons per capita for the U.S. population of about 220 million.

Within that prodigious total, the largest component is emplacements and embankments — dams, foundations, pavements, and the like — at 565 billion tons, an estimate that is considered "fairly rough" in comparison with others by the students' mentor, Professor Richard A. Rice. The above-ground "technomass" devoted to industry and commerce (including apartment buildings but not private homes and personal property) is 14.68 billion tons; that's equal in weight to a solid marble tower one city block square and 32.71 miles tall.

Personal property — houses, farm buildings, automobiles, and all the things people fill them with — weigh in at just over 3 billion tons, which means that U.S. families on average own 16 pounds of possessions (including homes) for every pound of their own weight. Structures in which we live weigh on the average about 200 times more than their occupants.

With all this assembly of "technomass," what's happened to the U.S. biomass? It's gone down but still is estimated at some 98 billion tons, of which 88 billion tons are trees. Thus, U.S. trees alone apparently still weigh six times as much as the above-ground, visible "technomass" of our civilization, say these calculating Carnegie-Mellon students. — *J.M.* □

Item	Weight (millions of tons)
Personal property	236
Private houses	2,550
Farm and forestry buildings	325
Apartment houses, hotels, motels	1,855
Institutional and government	1,046
Educational facilities	1,294
Transport and Utilities	2,405
Industrial and commercial	4,969
Above-ground technomass subtotal	14,680
Pavements and parking lots	24,116
Foundations, excavations, and dams	123,175
Highway and railroad embankments	417,960
Embedded groundmass subtotal	565,251
Total U.S. technomass	**579,931**

This is how the weights of U.S. works of technology stack up, according to the calculations of students in the Analysis, Synthesis, and Evaluation program at Carnegie-Mellon University. (*Data courtesy of Professor Richard A. Rice, Carnegie-Mellon University*)

Some fields seem even to be shorthanded. Theoretical physicists will continue to find "a very tight job market"; they comprise about one-third of the graduating Ph.D.'s but only one-sixth of the current physics labor force. On the other hand, there's a shortage of experimental nuclear physicists, the number of Ph.D.'s in that area having dropped "precipitously."

The hopeful young Ph.D. who wants a teaching job is likely to find the academic market hard to crack in every branch of physics. The reason is simple: as late as 1968, U.S. physics faculties were growing at the rate of 6 percent a year, and 35 percent of the faculty were then in the junior ranks. Since then, expansion has all but stopped. Faculty who were in the junior ranks in the 1960s now have firm grips on tenured positions, and until this group begins to reach retirement age, the lack of tenure-track positions will continue to "jeopardize the vitality of research-oriented physics departments," according to Professor Grodzins.— *J.M.* □

Making Simulators Part of the Nuclear Solution

Since Three Mile Island, sophisticated simulators to train nuclear plant operators have come into high demand. One program described at the 1979 Computer Simulation Conference in Toronto could replicate an emergency core cooling "campaign" that might last several days. The simulator could run in "real" time or many times faster to compress the training session. Such a simulator is at the Surry (Va.) Nuclear Power Station of the Virginia Electric and Power Co. (*Photo: Electronic Associates, Inc.*)

Less than a year after the Three Mile Island accident, there was a bull market for new computer simulators on which to train nuclear operators. Even by midsummer in 1979, writes A. Ben Clymer of Electronic Associates, Inc., a New Jersey hardware and software manufacturer, simulator suppliers were being asked to provide more sophisticated models that could simulate varied and more complicated malfunctions, and to replicate more elaborate plant monitoring systems. Simulators with price tags of $10 to $15 million are proliferating, he says.

The development is a natural consequence of the view, first put forth by the Kemeny Commission and now embraced by most nuclear engineers, that Three Mile Island's key lesson was not that nuclear reactors should be designed or built differently, but that their control rooms should be restructured and their operators better trained. (*See "Saving American Democracy: The Lessons of Three Mile Island," by John G. Kemeny, p. 64, and "Human Error in Nuclear Power Plants" by Thomas B. Sheridan, February, p. 23.*)

According to this line of thinking, says Donald H. Roy, head of engineering at Babcock and Wilcox, the problem at Three Mile Island was that the reactor posed questions for its operators very different from those they were trained to answer. What the operators lacked was the ability to understand the unexpected, to visualize every part of the system and what might be happening in it, Mr. Roy told the annual meeting of the American Society of Mechanical Engineers late last year.

For example, when the operators at Three Mile Island observed the movement of water from one building to another, they ordered the pumps shut down. They never considered that a relief valve might not be closed as indicated. Professor Larry Hirschhorn of the Management and Behavioral Science Center at the University of Pennsylvania concludes that this was not a question of the operators' basic intelligence. More likely, he told the American Association for the Advancement of Science early this year, it was a matter of treating the operators as "traditional workers" instead of "pattern-finders" and "problem-solvers." They should have been encouraged to develop what he calls "meta-skills — the skill of acquiring skills." Thus equipped, the operators could have successfully asked themselves what sets and sequences of failures could have created the conditions they confronted, what might happen next, and what was the best course to control the problem.

One way to correct some of these problems would be to reduce the amount of detailed information presented to the operators. Mr. Roy does not advocate additional automation; that would simply guarantee the addition of "immense new complexity." Training with ever more sophisticated simulators seems to be the better route, and Mr. Roy wants such simulators to consider the operator as a possible part of the problem as well as the solution in every accident scenario. —*J.M.* □

Materials

Foamed Metals: Stiffness Without Weight

Imagine a strip of metal or metal alloy filled with tiny, discrete "cells," or bubbles, of inert gas. Such material would weigh much less than a solid sample of equal volume, but would enjoy many of the strengths.

Still in the experimental stage, such foamed metals would be useful in many applications: from aircraft (foamed aluminum alloy helicopter blades are one specific possibility) to armor to nuclear reactors. In the latter case, "foamed plutonium alloy fuel would permit a compact reactor power source by allowing room within the fuel element for swelling and gas formation," says James W. Patten of Battelle Pacific Northwest Laboratories, who holds the patent on the fabrication of foamed metals.

The tricky business is not finding uses for foamed metals, but in making them. It's a complex, multistage process, and Mr. Patten, working under contract to the U.S. Energy Research and Development Administration, does it as follows:

□ Metal or metal alloy is sputtered in an inert gas atmosphere onto a substrate; the desired amount of gas is trapped within the sputtered material;

□ The sputtered material is removed from the substrate and is heated above its melting point until the desired degree of bubble coalescence, or "foaminess" is produced. Thick materials or those heated for long periods of time tend to develop overly large bubbles, which would reduce strength;

□ The foamed metal is quench-cooled.

According to Mr. Patten and colleague E. N. Greenwell, "gas trapping during sputter deposition is a well-documented phenomenon, although trapping mechanisms are poorly understood." They believe their method is "useful for preparing foamed metals and metal alloys from any metal or other material of which a body containing entrapped inert gas can be prepared." Notable exclusions include mercury and some of the alkali metals, which cannot form a rigid structure under ordinary conditions.

Especially tantalizing is the possibility of producing foamed alloys in space. "It is felt that the zero-gravity environment will be essential to prevent density-driven bubble segregation and retain pre-formed shapes in anything but the simplest geometries and smallest sizes of useful engineering materials," predicts Mr. Patten. Small-scale experiments with aluminum sputtered in argon in two National Aeronautics and Space Administration space flights indicate that such materials could be more readily made outside our gravitational field. — *L.A.P.* □

Manganese: A Dark Horse in Metals

It's not that manganese is useless. It's rather that we've sought substitutes because it is rare (in the U.S.) and expensive (nearly 60 cents a pound).

But commercial development of the "manganese nodules" which lie in plenty on the floors of many of the world's oceans — mainly motivated by our need for cobalt, copper, and nickel — could change all that.

Production of nodules at a rate which would provide half of our cobalt needs would yield perhaps as much as 750,000 tons of manganese a year. Total U.S. consumption today is hardly more than that, and the prospect of this prodigious outpouring of manganese suggests to Professor Nicholas J. Grant of M.I.T. the development of a wholly new manganese-based alloy system. If world manganese prices can be cut in half by the new bonanza, the new manganese-iron materials could well turn out to be "the second-cheapest (next to modern steels) alloy system available," Professor Grant says.

Already, manganese is an essential constituent in steel — used in very small amounts (a few per cent) to eliminate embrittlement due to sulfur and (0.4 to 2 per cent) to provide strength, toughness, and ductility at low temperatures.

And there is spotty — and encouraging — knowledge of very simple alloys of iron with much higher manganese content — 25 to 40 per cent. These materials have important attributes: good strength and ductility at room temperature *and* at temperatures as low as −180° C. (important for cryogenic applications), with good welding performance. There are also stainless steels containing 30 to 40 per cent manganese which show unusually great strength at high temperatures (650° C.). More complex alloys simply have not been tried, Professor Grant says, and "a well planned alloy development program" would pay great dividends. — *J.M.* □

Last Line

On the Semantic Dissolution of Risk

A major chemical company recently launched an image-oriented advertising campaign based on the premise that "without chemicals, life itself would be impossible." The premise can be interpreted as meaning "chemicals are good and necessary for life," and therein lies a problem in semantics and logic — not unlike that involved in a simplistic, general condemnation of "chemicals" in foodstuffs.

Certainly, all substances have a chemical nature that can be precisely delineated. But experts in the various scientific disciplines use appellations more limiting and therefore more useful than "chemicals" to refer to substances of particular interest. Examples include such nouns as "minerals," "polymers," "antioxidants," "antibiotics," "toxicants," "pesticides," "poisons," and so on. The connotations of these nouns are much less prone to subjective distortions than those of the word "chemicals," which to the layperson probably means something akin to "substances put into the environment by human activity that would otherwise not be there."

The advertising paradigm is built on the assumption that *all* substances are "chemicals." But by the lack of a disclaimer or qualifier, the advertisment copy takes the general public on a breathtaking leap of illogic that attempts to link generally and amicably things such as carcinogens, mutagens, and toxic materials with life.

The paradigm having been disproved, the advertising claim rings hollow. Pity is, the company involved produces numerous useful products and services, but has risked loss of corporate credibility by giving notoriety to such an arguably misleading claim.

Most would agree that risk is an inherent part of living. But we all try to minimize the risks of life insofar as possible while reaping its benefits. Sweeping generalizations on risk — in advertising or from whatever quarter — add a factor of ignorance to risk-benefit considerations that cannot be tolerated if we as a nation are to continue to enjoy the fruits of technology and the blessings of a biosphere as free from human insults as possible. — *L.A.P.* □

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Lowering the Price of Interferon

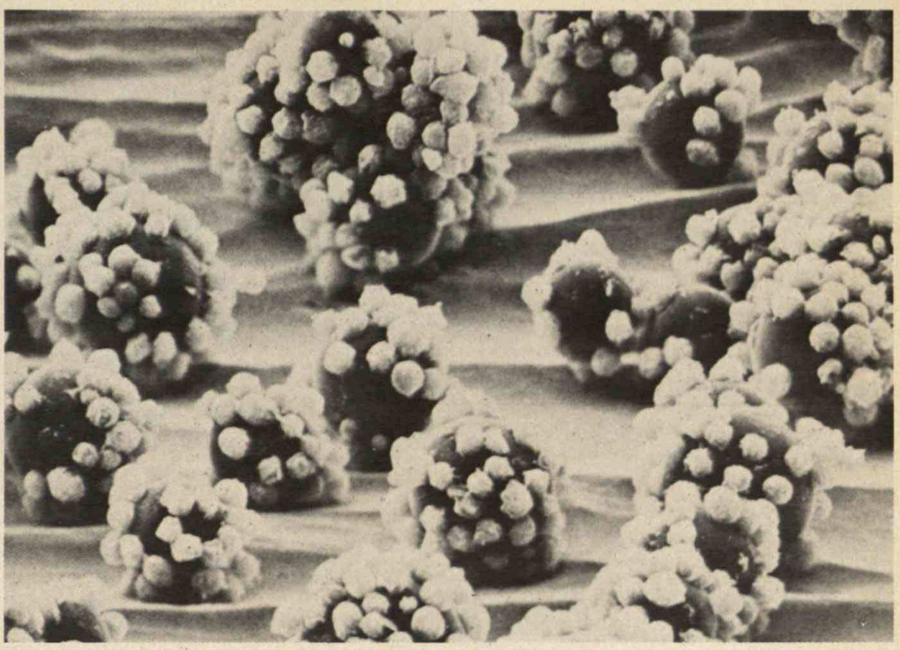
Two years ago M.I.T.'s Cell Culture Center announced that it could grow vastly increased numbers of cells by using a new medium: tiny beads of a starchy material called dextran (*see "Seven Billion Cells per Liter," June/July 1978, p. 30*).

Now that process is being applied to human interferon, a scarce natural substance that seems to be a powerful weapon against cancer and virus infections. M.I.T.'s patent on the process utilizing the tiny beads has been licensed to Flow Laboratories in McLean, Va., and a Flow official has told the *Boston Globe* that negotiations are underway with the National Cancer Institute for production of 50 billion units of human interferon for clinical tests of antitumor activity.

M.I.T. experts guess that the process might lower the cost of interferon from $50 to $2.50 per million units; at the $50 price, a full course of interferon treatment for a cancer patient would cost some $30,000.

Meanwhile, interferon research continues at M.I.T. Many types of interferon exist, produced from different types of cells, and the speedier, lower-cost production technology will make possible rapid momentum in studies of their different properties. □

A scheme for vastly increasing the productivity of cell culture processes by using tiny beads of dextran as a medium (*below*) may be coming into its own; the process has been licensed, and it's being used to grow interferon, which appears to be a powerful anti-viral agent.



The Diesel: Dangerous as Well as Dirty?

Experiments by William G. Thilly, associate professor of toxicology, and his associates at M.I.T. have shown for the first time that the complex, exotic chemicals formed in diesel engine exhaust cause significant genetic damage to living human cells.

By itself, this finding does not mean that diesel soot can be correlated with cancer or any other disease; it simply serves as a warning: if the compounds from soot cause mutations in genes, occasionally they *may* damage an organism's ability to function or reproduce. Therefore, "we should consider diesel soot a potential hazard for humans," Professor Thilly told Robert Cooke of the *Boston Globe* early this spring.

The hypothesis is that some of the obscure organic chemicals found in diesel emissions are converted into mutagenic chemicals by normal metabolizing enzymes, especially those found in the liver. This concept of metabolic activation is new, and Professor Thilly thinks it may be a "productive" area for future research.

His studies, originally financed by the Department of Energy, are continuing at the new Center for Health Effects of Fossil Fuel Utilization now in place at M.I.T. Its work is supported by federal and industrial grants, including grants from General Motors, the nation's largest producer of diesel engines. □

For Safety, Fly Home

Air travelers are significantly safer on U.S. domestic flights operated by major airlines than on international flights, whether operated by U.S. or foreign carriers. But there is essentially no safety difference among U.S. domestic airlines.

Those are the major conclusions of an extensive study of airline safety by Arnold I. Barnett, associate professor of operations research, and two of his graduate students, Michael Abraham and Victor Schimmel, in the Sloan School of Management.

The odds of surviving a randomly chosen U.S. domestic flight in the 1970s were about 2.6 million to one. For people on international flights, the odds were eight times poorer; there are "substantial" and "statistically significant" differences among international carriers. The advantage among the latter rests with the larger airlines from "westernized" countries; the worst records belong to MALEV (Hungary) and Egyptair. Outstandingly safe international carriers include Air Canada, Lufthansa, Qantas, and Finnair. □

Ending the Standoff on the Campuses

How much right has government to tell higher education what to do?

That became a crucial question in the 1970s, as government steadily increased its laws and regulations affecting U.S. campuses. As the cadre of civil servants increased to enforce the new regulations, colleges and universities increased their staffs of lawyers and administrators to deal with the growing number of federal agents. And the ensuing interaction led "to little more than bad feeling on all sides," says the Sloan Commission on Government and Higher Education.

Though there are no easy answers, the commission is convinced after three years of study that "much can be done to improve the ways in which the government and colleges get along," and it offers a series of specific recommendations in a final report issued this spring:

□ Creation of a new Council for Equal Opportunity in Higher Education, in which are consolidated all the government's initiatives for enforcing equal-opportunity laws as they apply to colleges and universities. The university faculties should be more involved in setting colleges' goals and monitoring progress, but the new council would have broad en-

forcement responsibility.

☐ The central purpose of federal financial aid to students should be to assure that "no high school graduate who wants further education is denied it because of financial need." Programs should be simplified and focused more on students' needs and less on institutions' needs, and there should be a National Educational Loan Bank to provide unsubsidized loans to college students.

☐ Federal funding of academic research has resulted in "enormous contributions to the nation's health, prosperity, and security" in the last 40 years, transforming "the leading American universities into centers of scientific discovery." All this should continue, with funds for "a modest degree of long-term real growth" and procedures protecting universities from year-to-year funding fluctuations. The commission wants to change the attitude of government and universities alike "from the present rancorous tone to one of mutual respect"; it believes a corps of sophisticated federal research auditors would be helpful.

☐ Medical schools, which have been subject to "the kinds of direct controls used in other parts of the health-care system but not in other areas of higher education," need the help and understanding of a national commission on medical education and its relation to health care.

In a time when budgets are tightening and enrollments are going down, higher education must have "the largest possible scope for autonomy," the commission says. "But it cannot consistently call for less government and more money at the same time."

Carl Kaysen, David W. Skinner Professor of Political Economy at M.I.T., was the Sloan Commission's director of research; and Louis W. Cabot, chairperson of the Cabot Corp. who is a life member of the M.I.T. Corporation, was chairperson of the commission. ☐

Keeping Plutonium Where It Belongs

President Carter's policy of international constraints on nuclear fuel reprocessing to limit the availability of plutonium for nuclear weapons (*see "Balancing Nonproliferation and Energy Security" by Joseph S. Nye, Jr., December/January 1979*) has failed. There is simply too much pressure overseas — and too much technology — for spent fuel reprocessing, says an international commission led by George Rathjens, professor of political science.

The report by Professor Rathjens' group was widely interpreted as a setback for President Carter. But Professor Rathjens doesn't agree with this assessment, he told Robert Cooke of the *Boston Globe*. "There was never any realistic expectation that . . . we would be able to stop reprocessing on a world scale," he said, and he thinks the important thing now is a convergence of views on four realistic issues:

☐ Nuclear waste disposal and reprocessing are two separate issues; reprocessing is not necessary for disposal.

☐ Plutonium, which is a natural product of most fuel reprocessing, has little or no economic advantage in conventional reactors; the need for plutonium arises only with plans for breeder reactors.

☐ Research reactors can be operated with uranium of low or medium enrichment. This is important, Professor Rathjens told Mr. Cooke, "because many research reactors now in use are fueled with highly enriched uranium that is suitable for weapons."

☐ Since controlling reprocessing is not feasible, efforts to prevent proliferation depend on "improved international safeguards" against the diversion of reactor fuel for weapons use. ☐

Help Wanted: Engineers Welcome

The large volume of "help-wanted" ads in Massachusetts newspapers is cited by the Massachusetts High-Technology Council as corroboration of its findings that a shortage of technical personnel threatens the prosperity of the state by 1982. At least 33,000 new technical, professional, and paraprofessional jobs will be added by 65 high-technology companies by 1982, and to help fill these slots, colleges and universities are urged to increase enrollments and switch resources from nontechnical to technical fields.

	7/1/79- 12/31/79	Year Ending Dec. 31 1980	1981	1982	Total Increases 7/1/79- 12/31/82
Technical Professionals	1,375	3,160	3,268	3,842	11,645
Technical Para-professionals	1,282	2,808	3,148	3,300	10,538
Assemblers/Production Operators	1,082	2,987	3,284	3,892	11,245
Totals	**3,739**	**8,955**	**9,700**	**11,034**	**33,428**

High-technology companies in Massachusetts say they want to double their number of technical engineers before the end of 1982, and they worry that their growth may be constrained by "a widespread shortage" of qualified personnel.

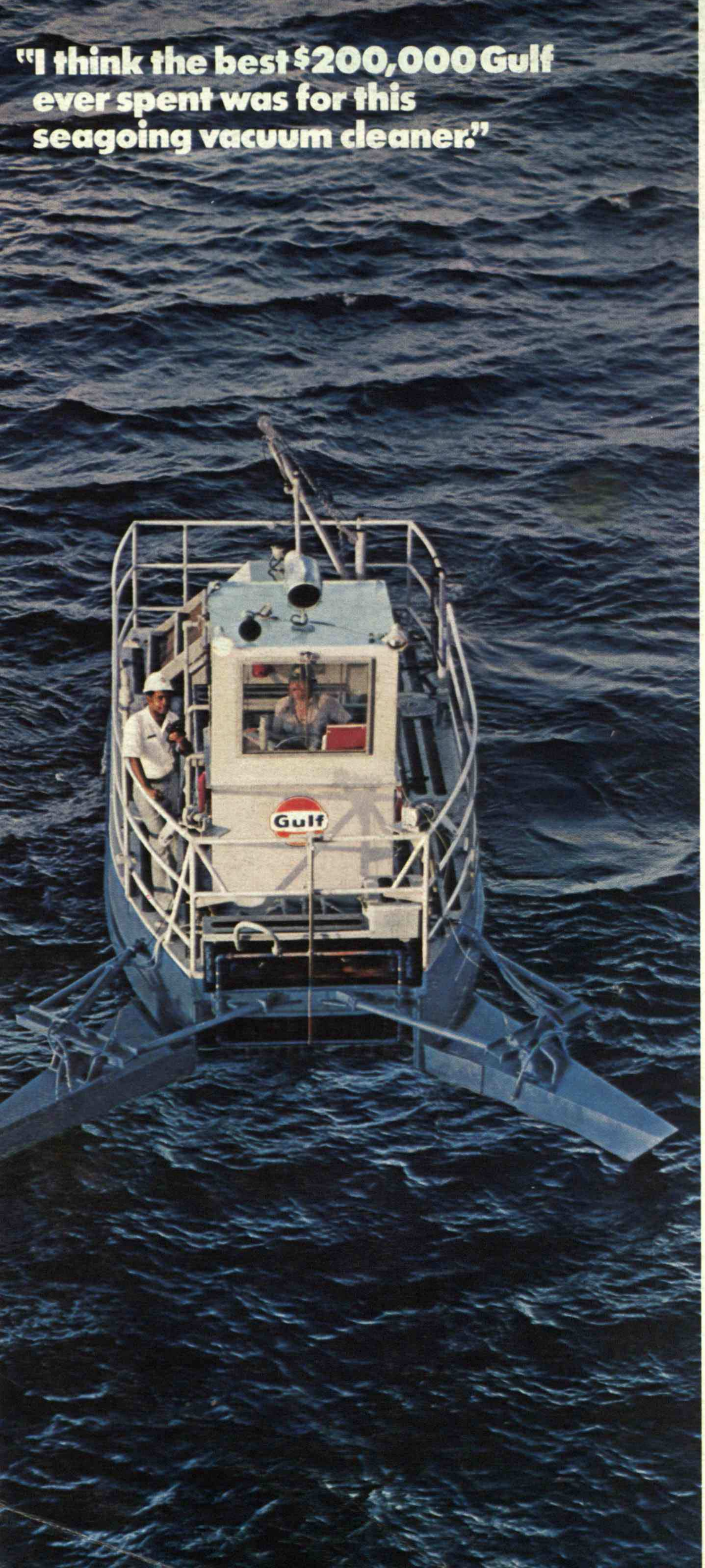
"There is definitely a supply/demand crisis," says Alexander V. D'Arbeloff, chairman of the Massachusetts High-Technology Council (he is chief executive officer of Teradyne, Inc.). "Our high schools, colleges, and universities are simply not supplying qualified personnel in sufficient numbers to meet the projected demand."

The shortfall covers a broad range of occupational skills, from technicians and programmers to engineers and scientists.

The MHTC asked its 93 member companies in Massachusetts — total employment, nearly 200,000 — what new human resources they will need before the end of 1982 in professional and paraprofessional assignments. The answers from 70 per cent of the members: over 11,500 new professional workers — by far the largest number of them electronic/electrical engineers — and over 21,000 paraprofessionals — including nearly 6,000 technicians and over 11,000 assemblers/production operators. These figures are considered conservative, since MHTC's survey respondents represent less than half of the high-technology sector in Massachusetts.

Even if local companies are able to attract most of the graduates, Massachusetts schools, colleges, and universities will not meet these needs by 1982, the MHTC said. So the companies will also seek workers from outside the state, but there is not wide optimism for the success of that effort: "The tight national market for technical talent, plus the high cost of living in Massachusetts, are major obstacles," says MHTC.

So MHTC's recommendations focus on means to increase Massachusetts college and school enrollments in technical fields: reallocate resources from low-priority fields to science, engineering, and mathematics; provide tax incentives for financial grants, scholarships, research, and other forms of support for higher education; provide matching grants from MHTC members to encourage more science and engineering teaching; provide programs for liberal arts graduates to switch to technical careers . . . ☐



"In the last year or so, Gulf Oil has spent about $250 million to protect the environment around Gulf drilling rigs, mines and refineries," says Manuel Andino, Gulf's Utilities Director at San Juan, Puerto Rico.

"If any oil gets into the water, the Bay Skimmer can pick it up fast."

"But I'd say the Bay Skimmer was one of their best investments: $200,000 for a seagoing vacuum cleaner for San Juan Harbor.

"We've had a refinery here for 25 years. About 15 million barrels of Gulf crude oil and refined products pass through this port each year.

"That's a lot of oil, and if *any* of it gets into the water, the Bay Skimmer can pick it up fast. It was tailor-made for this job. We can go right through an oil slick, and a big belt in the bow simply lifts the oil off the water.

"The Bay Skimmer is just one detail in Gulf's overall investment in protecting the environment while keeping the oil flowing. Responsible energy management is a big challenge. It's expensive and it's complex. But it's a job worth doing, and I think we're doing it right."

Gulf

Gulf people: energy for tomorrow.

Gulf Oil Corporation